BULLETIN

OF THE

SCIENTIFIC LABORATORIES

OF

DENISON UNIVERSITY

Volume XVI Articles 1-3 Pages 1-220

EDITED BY

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GRANVILLE, OHIO, JUNE, 1910

THE METAMORPHISM OF GLACIAL DEPOSITS.[1]

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INTRODUCTION

Glacial drift metamorphosed to a conglomerate has been studied in several parts of the world. A detailed description of such a conglomerate in South Australia, identified as a Cambrian tillite, has recently appeared;[2] glacial formations of the same period have been studied in China.[3] In India,[4] Africa,[5] and South Australia,[4] glacial conglomerates of Permian age have been carefully investigated.

The present brief inquiry is confined to glacial sediments of the Pleistocene period. The conclusion arrived at, from a field study of these sediments in central New York and in northern and central Ohio, is that locally, at least, the alteration of a part of the

1 Published by permission of the Ohio Geological Survey, but the author is responsible for the opinions expressed. Read before Section E of the American Association for the Advancement of Science at Baltimore, 1908. Reprinted from the *Journal of Geology*, vol. XVII, No. 5, July-August, 1909.

2 Rev. Walter Howchin, "Glacial Beds of Cambrian Age in South Australia," *Quart. Jour. Geolog. Soc.*, vol. LXIV (1908), pp. 234-59. The same author made a preliminary report in 1901, *Trans. Roy. Soc. of South Australia*, vol. XXV, p. 10.

3 Willis, Blackwelder, and Sargent, *Research in China*, vol. I (1907). Carnegie Institution, Washington.

4 C. D. White, *American Geologist*, vol. III (1889), pp. 306-11. Chamberlin and Salisbury, *Geology*, vol. II (1906), pp. 632-35.

5 C. D. White, *op. cit.*, pp. 303-6. Chamberlin and Salisbury, *op. cit.*, pp. 635-38.

drift is under way, that is, it has reached an appreciable stage of metamorphism; furthermore, that this fact may be used in differentiating the drifts of some of the Pleistocene epochs.

In this paper the term "metamorphism" includes all alterations concerned in the transition from degradational products to solid rock again.[6] It is not possible to observe many stages in this cycle because of the fact that so far as present investigation goes, the glacial periods are separated by long lapses of time, and because of the further fact that most phases of metamorphism require a physical environment that precludes observation.

FIELD DATA

The glacial deposits that occasioned this study are characterized by the following features:

1. *Color.*—All the unmodified drift concerned is bluish; it is felt that this is the constant color of the deposits because the observations were made either along stream banks that were being undercut, thus giving fresh exposures, or along shore cliffs where the waves are undermining the drift. In most of the exposures the color condition is emphasized by contact with drift which differs in color; the usual association is a yellow and sometimes oxidized horizon of more recent glacial accumulation beneath which is the zone of bluish drift. So far as can be ascertained, the color is not dependent upon the content of the drift. The surfaces of the included bowlders, large and small, and the entire matrix of clay, are uniformly of a bluish cast. This characterization applies equally to these deposits in widely separated parts of Ohio as well as throughout a considerable region of central New York. Because of a lithological difference in the rock formations that were eroded, as shown by a study of the bowlders and pebbles in the drift, one would expect some variation in color; this, however, is not the case.

2. *Texture and structure.*—As is the case with nearly all types of glacial deposits, we have here a great variety in texture. The till of some exposures is very fine, and quite free of even small bowlders; other exposures contain many, and large, erratics. More uniformity in texture, however, is found in the water-laid drift belonging to this study; usually, it is fine, even silty.

All these deposits apparently show the effects of great and long-continued pressure. They are dense in structure. This com-

[6] C. K. Leith, *Journal of Geology*, vol. XV (1907), p. 313.

pactness is manifest in the angle at which the cliff-faces stand, not infrequently overhanging; also in the tendency of bowlders, showing on the surface of the cliffs, to hang even after more than half their mass has been exposed. In some cases I was able to satisfy myself, by tracing this hard horizon back from the cliff, that it constituted the proverbial "hard pan" of well-drillers. Furthermore, I have seen several dug wells being made, in which case there could be no doubt about the identity of this compact horizon and the bluish till.

3. *Obvious physical alteration.*—In several cliff-exposures the contact between this hard deposit and the superjacent drift is a series of sags and swells representing either an irregular deposition of the subjacent material or its unequal erosion later (fig. 1). But the relation of the inequalities precludes subaerial erosion; the irregular surface is either genetic, or it was produced by the erosion of over-riding ice.

Contortion and folding is observed particularly in the water-laid deposits (fig. 2). This alteration has been studied in material varying form silt to rather coarse sand. I have examined many exposures, both modified and unmodified, which show jointing and faulting (figs. 3, 4, 5). In no case was I able to show conclusively a displacement of more than three inches, and this maximum displacement was always in the water-laid drift. It is quite impossible to measure movement along a fault-plane involving only till. On the theory that every joint is a fault,[7] we may assume a displacement even though it cannot be measured. In all exposures of till thus altered, the joints are nearly vertical, and in systems (fig. 6). In the water-laid deposits this characterization is less clear. It should be stated, furthermore, that along most of the joint-planes or fault-planes there has taken place either a secondary alteration or a deposition from percolating water (fig. 2). In some cases this secondary deposit has weathered away more rapidly than the wall material; in others, less rapidly.

4. *Weathering.*—Leaching in a relatively short time removes carbonates, especially from surface deposits. Only at a considerable distance from the top do we often get evidence of carbonates in the superjacent drift. This leaching by ground water is the first step in the cementation process always going on at lower horizons. The bluish compressed drift invariably shows the presence of cal-

[7] G. F. Becker, *Bulletin of the Geological Society of America*, vol. IV (1893), p. 72.

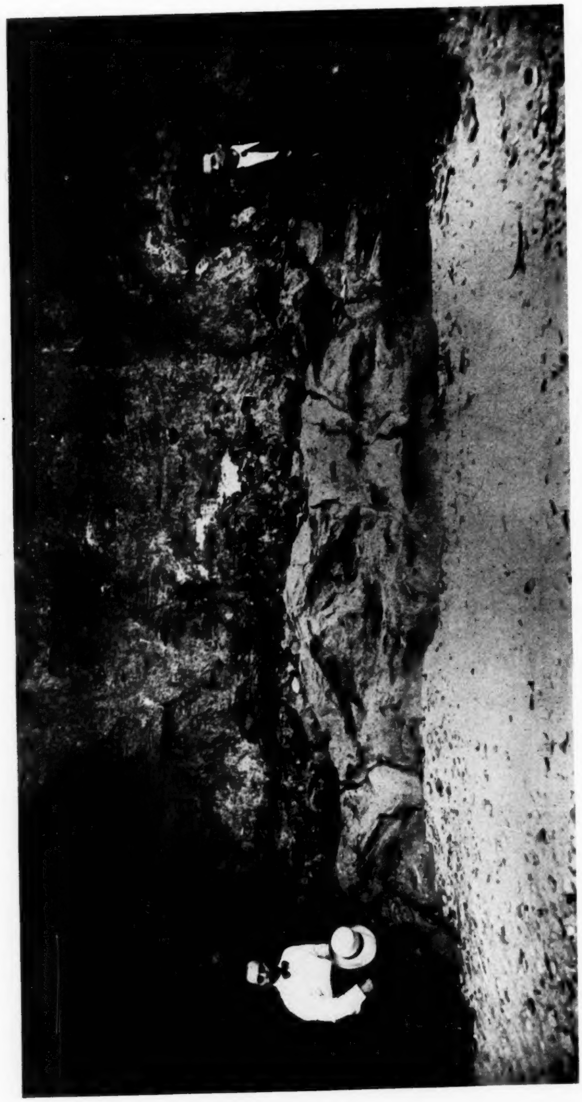


FIG. 1.—Buried valley west of Cleveland. At the base is bluish till, apparently ice-eroded; above is compressed and slightly distorted silt.

cium carbonate. This fact does not imply that the drift had never lost its carbonates through leaching; it means only that now this particular cement is present, deposited probably from solution. No further observation was made to determine the cements or other chemical content of this dense drift. It is tentatively assumed that the universal bluish color is a result of alteration, though it cannot be disproved that this drift in both New York and Ohio was not bluish from the time it was deposited, but the force of this possibility is somewhat lessened by the fact that there is considerable difference in the content of the drift of these areas; it is assumed, further, that this color probably represents a chemical alteration accompanying metamorphism, a change brought about, under particular conditions, by ground water in unconsolidated sediments. The nature of these conditions will be discussed later.

The superjacent yellow till usually shows the results of weathering, especially near the surface; but in all parts there is evidence of leaching.

AGENCIES OF ALTERATION

Normally most of the changes going on in the regolith are due to pressure and to chemical reactions. The pressure is that of the superincumbent mass which varies directly with the depth. Chemical reactions are chiefly associated with water which is always a solvent, but the water of glacial drainage, since it comes in contact with such a wide range of rocks, is highly solvent and has capacity for other chemical reactions.

Chemical.—Outside of arid regions, sediments contain a good deal of water. In all climates circulating ground water exists at some depth; the more humid the climate, the higher is the groundwater level. It is probable, however, that a special condition exists in sediments subjacent to an ice-cap; here, on account of the constant melting of the basal ice caused by radiation from the earth,[8] the supply of water is so great that a condition of saturation exists in these sediments. This condition of saturation was certainly the case during both the advance and retreat of the ice-sheet within the north-sloping side of the St. Lawrence drainage basin. This northward slope in conjunction with the wall of ice caused a ponded condition of drainage. Beneath these bordering lakes, sediments were always in a condition of saturation.

FIG. 2.—Deposits in a buried river valley west of Cleveland; this material was crumpled and distorted; later it was faulted; vein deposits occupy the fault-planes.

Underneath an ice-sheet, it is reasonable to suppose that oxidation is subdued, but even in the absence of atmosphere, sulphides may be slowly changed to sulphates. Since this glacially accumulated rubbish may contain constituents previously weathered, it is possible that deoxidation also takes place.

Throughout the distance between the Mohawk Valley in New York state and Michigan at the western end of Lake Erie, limestone formations come to the surface. These outcrops suffered degradation by the ice-sheet. Other limestone horizons farther north, in part of this distance, also contributed to the glacial load of debris. This content of limestone in glacial sediments was partly dissolved even by the cold water; no rock-forming constituent is

Fig. 3.—Disturbed and faulted bluish till exposed along Dugway Brook, Cleveland.

more easily affected by water. The resulting carbonated water actively attacked the silicate minerals at least. Solution and later precipitation is always an accompaniment of ground-water circulating through glacial sediments, and further reactions will give different solutions.

The decomposition of rock-constituents is usually accompanied by hydration. This is almost invariably the case in oxidation and carbonation. In unconsolidated materials beneath an ice-cap hydration would be an active agent in alteration.

[8] Chamberlin and Salisbury, *Geology*, vol. I (1904), p. 263.

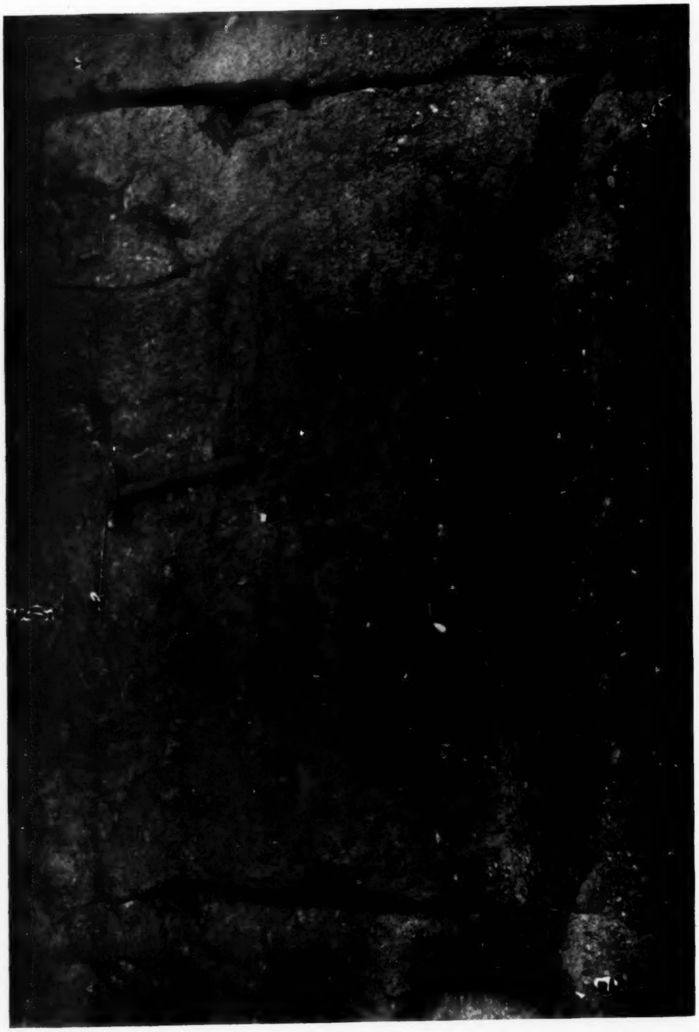


Fig. 4.—Jointed bluish till on shore of Lake Erie at Conneaut, Ohio. The cliff-face is a joint-plane at right angles to the two conspicuous joints.

Pressure.—In the deeper-seated areas of the fragmental zone of the earth's crust, pressure has long been regarded as playing an active part in the alteration of rock. In the case of the superficial sediments under discussion there appear to be three sources of pressure:

1. The weight of drift overlying a given horizon in a mass of sediments exercises a compressive force; in the deeper-buried sediments this force is stronger. In consequence of this compression there is greater facility in capillary action, that is, waters move more slowly through these sediments, and precipitation is increased.

2. During the continuance of an ice-invasion, the weight of the ice itself bore down on the unconsolidated materials, thus acting as a factor in their alteration. In discussing this, however, it must be granted that an ice-sheet degrades, first of all, the regolith. It is a fact nevertheless that in certain localities, some of the previously aggraded sediment was not removed by ice.[9] These deposits may be the drift of an earlier ice-invasion; in any case, wherever not removed, it was subject to the great weight of the ice-sheet. This weight can be computed only approximately. Some observations have been made on which are based conclusions in reference to the surface slope of ice-caps; this data includes a study of both existing ice areas and bands of drift constructed by former ice.[10] A conservative estimate of the depth of Wisconsin ice over the Erie basin is at least 2,000 feet. This figure is based on two considerations: the present difference in level between Lake Erie and altitudes south that were covered by ice is about 800 feet. The ice reached south of the Erie basin approximately 200 miles; if its surface sloped even six feet per mile, this would represent a depth of 1,200 feet which, plus the 800 feet due to the differenece in altitude, makes approximately 2,000 feet. The basal pressure per square foot for clear ice of this thickness would be 115,500 pounds.

In New York state, there is a greater difference in altitude, even when we neglect the overdeepened portions of the major Finger Lake valleys. The range in altitude alone would give 1,500 feet of ice; this, in connection with the surface slope of the ice, would give a depth of approximately 2,500 feet, which represents a basal

9 R. S. Tarr, *American Geologist*, vol. XXXIII (1904), p. 287. H. L. Fairchild, *Bulletin of the Geological Society of America*, vol. XVI (1905), pp. 53-55. F. Carney, *Journal of Geology*, vol. XV (1907), pp. 579, 580.

10 Chamberlin and Salisbury, *Geology*, vol. III (1906), pp. 356-58.

Fig. 5.—Jointed bluish till on shore of Lake Erie, east of Cleveland.

pressure per square foot of over 144,000 pounds. Both of these computations, it is noted, are for clear ice. Knowing that the ice-sheet must have carried constantly some drift, these figures undermeasure, perhaps, the real pressure. That the subjacent deposits would be compressed by the weight of this ice is undebatable.

Adams has shown that a condition of rock-flowage was induced in marble by a pressure of about 18,000 pounds per square inch.[11] The pressure on the sediments, as discussed above, is in either case more than 9,000 pounds per square inch.

Another possible factor associated with the question of pressure is the development of heat. Even the laggard motion of an ice-sheet represents energy which through basal interference is converted into heat. This heat may have no other manifestation than the wastage of ice near the friction zone. Whether a dead load upon compressible matter evolves heat in the absence of appreciable movements along planes developed in this matter is a question on which the writer is not informed.

3. It is thought, furthermore, that pressures are evolved by chemical changes going on in this drift. Such pressure is an accompaniment of hydration when the hydrated mineral is confined as must be the case in drift subjacent to a burden of at least 9,000 pounds per square inch. Other chemical changes also tend to increase the bulk of the minerals being altered.

SUMMARY.

In defining its age and origin the most suggestive feature of this drift is its color which is constant over widely separated areas. The folding, jointing, and faulting might be caused by Wisconsin ice readvancing over drift it had recently deposited; faulted sediments subjacent to till of such a readvance are shown in fig. 7.

It is possible that the bluish till is the product of the oncoming Wisconsin ice. If the pressure of an ice-cap is the most active agent of alteration, and the time factor is secondary, it is even probable that both the bluish and yellow drifts are Wisconsin; but the following observations tend to diminish this probability:

About three miles northeast of Newark, O., along Shanee Run, and again two and one-half miles southeast of Newark along Quarry Run, I have seen the same bluish till, at the former outcrop in contact with the yellow drift, at the latter showing only in the

11 F. D. Adams, *Bulletin Geological Society of America*, vol. XII (1901), p. 457.

FIG. 6.—Water-laid drift overlying bluish till which contains two systems of vertical joints. This till is very stony, mostly limestone.

bed of the stream where it forms a riffle. These localities are just within the margin of the Wisconsin drift, where the ice was attenuated as well as short-lived. It is certain that in these two cases time has been the important factor in the alteration; no great mass of ice ever stood here for even a short period. If this hard bluish till was deposited by Wisconsin ice, its color is genetic; but on this hypothesis it is difficult to understand why the superjacent drift is yellowish, and the line of division is so sharp.

But there can be no question that the old valley of Rocky River, west of Cleveland, was buried by a pre-Wisconsin ice-invasion, presumably the Illinoian. The bluish till in this buried stream-course is apparently identical with the dense drift referred to in central Ohio and New York.

FIG. 7.—Faulted glacial gravels. Yellow till has been removed from the top.

These facts suggest the following conclusions:

1. Glacial deposits, regardless of their constituents, when buried for a long time appear to become compact, and bluish in color. This assumption does not disregard the possibility that some deposits have always been bluish. The dozens of exposures studied in both states show a great variety of rock-constituents, as well as wide variation in the general texture of the drift; this color is constantly noted in drift ranging from the fine silt to an ex-

tremely stony till (figs. 1, 2, and 6[12]). I have nowhere noted a gradual blending from one color to the other, nor streaks of the yellow penetrating the bluish, as has been described in the Central West.[13] It is very likely that upon sufficient exposure to weathering agents the blue till would become lighter in color; but because of its indurated condition it weathers less rapidly than does the superficial Wisconsin drift.

2. An ice-cap passing over glacial sediments, particularly till, develops in its joints and faults (figs. 2-4) either because the till on account of inconsistency in structure yields differentially to the weight, or because differential strains are induced by topography; these fracture lines are approximately vertical (figs. 5, 6). I have observed this jointed condition of till in central and northern Ohio, and in New York along creeks tributary to the outlet of Keuka Lake.[14]

3. The altered drift described in this paper contains abundant carbonates, probably deposited from circulating ground water, whereas carbonates are either absent or less conspicuous in the superjacent drift of later origin. This difference between the two drifts is apparent even when tests are made near their contact; the observation holds for exposures studied in all the areas under consideration.

4. The color in the case of the drift above described, its indurated condition, and the jointing appear to be associated with the change or metamorphism which develops tillite from glacial drift.

5. I believe that so far as the regions considered in this paper are concerned two Pleistocene epochs are indicated by a contact of the bluish and yellowish till.

12 Cf. *Journal of Geology*, vol. XV (1907), pp. 575, 577, for other pictures illustrating the same variation in texture.

13 F. Leverett, *Monograph XLI*, U. S. Geolog. Surv. (1902), p. 272. *Ibid., Monograph XXXVIII*, U. S. Geolog. Surv. (1899), p. 28. W. H. Norton, *Iowa Geological Survey*, vol. IX (1898), pp. 480-82.

14 *Journal of Geology*, vol. XV (1907), pp. 583, 584.

PRELIMINARY NOTES ON CINCINNATIAN AND LEXINGTON FOSSILS OF OHIO, INDIANA, KENTUCKY, AND TENNESSEE.

Aug. F. Foerste.

By far the best fossils for the accurate discrimination of the various Cincinnatian and Lexington horizons of the area of the Cincinnati geanticline are the bryozoans. Possibly, in the future, the ostracods may be of great service. If the brachiopoda, and some of the other more common groups of fossils are to be added to this list, a much more extended subdivision of forms, based upon slighter differences, will be necessary. It is not likely that such subdivisions of recognized species will commend themselves to those who are engaged in the broader problems of paleontology, but these subdivisions are necessary if all the available material is to be employed in the discrimination of the different faunas at the different horizons. Whether these subdivisions are to appear in literature as species or as varieties is another question. A great convenience of the Linnean binomial system is its restriction of names to two terms. This convenience is lost if too many terms appear under the trinomial form of varieties.

The Cincinnatian formations are rich in forms which are in the process of evolution, resulting in numerous groups within which the varieties are closely connected by abundant intermediate forms. In this wealth of material some investigators will see species where others see only varieties, or scarcely even the latter. In this case it will be well to remember that the object of the investigation will often determine the attitude of the investigator. The present paper is for the purpose of supplying material for the discrimination of Cincinnatian horizons.

Incidentally, it has been attempted to determine more accurately the type forms and horizons of some of the species already described. The best excuse for this preliminary publication of material is that it has already brought fruit in the renewal of investigations in the field from which former students, owing to other and more important interests, had departed.

The following classification of Cincinnatian and Lexington strata is here adopted:

Series	*Formations*	*Beds*
Cincinnatian	Richmond	Elkhorn
		Whitewater
		Saluda
		Liberty
		Waynesville
		Blanchester division
		Clarksville division
		Fort Ancient division
		Arnheim
		Oregonia division
		Sunset division
	Maysville	Mount Auburn
		Corryville
		Bellevue
		Fairmount
		Mount Hope
	Eden	McMicken or Paint Lick
		Southgate
		Economy
	Utica	Fulton
	Cynthiana	Nicholas
		Greendale
		Perryville
Upper Mohawkian	Lexington	Paris
		Wilmore
		Logana
		Curdsville

The Arnheim bed has been separated into two divisions, the upper or Oregonia division, exposed in the Blacksmith hollow, northeast of the railroad station at Oregonia, Ohio, being characterized by the introduction, at the base, of the characteristic Richmond fossils: *Leptaena richmondensis-precursor, Rhynchotrema dentata-arnheimensis,* and *Dinorthis carleyi.* On the eastern side of the Cincinnati geanticline, the lower half of the Arnheim is much less fossiliferous, and is terminated by a layer containing *Platystrophia ponderosa.* Southward, in Kentucky, this horizon consists of comparatively unfossiliferous argillaceous limestones, containing comparatively few specimens of this *Platystrophia.* A typical exposure is found about half a mile southwest of Sunset, along the road to Day's Mill, and from this locality the term Sunset division has

been chosen for the lower Arnheim. It is suspected that this lower part has closer affinities with the Mount Auburn fauna than with the upper Arnheim.

The Saltillo limestone, characteristically exposed along the Tennessee river in Western Tennessee, was described in the January-February number of the Journal of Geology in 1903. It contains the following fauna:

Trematis punctostriata, Hall; *Schizocrania rudis,* Hall; *Leptaena tenuistriata,* Sowerby, var; *Leptobolus lepis-cliftonensis; Lingula waynesboroensis; Dalmanella; Zygospira recurvirostra,* Hall; *Clidophorus* sp., near *neglectus,* Hall; *Whiteavesia cincinnatiensis,* Hall and Whitfield; *Calymene platycephala.*

The Hermitage limestone, typically exposed in Davidson county, Tennessee, and thence southwestward, through Williamson and Maury counties, was accurately described by Hayes and Ulrich in their Columbia Folio, published in the fall of 1903. It appears to be the stratigraphical equivalent of the Saltillo limestone, and contains the following species, according to Ulrich:

Prasopora patera; Prasopora simulatrix; Leptobolus lepis; Dalmanella fertilis; Zygospira recurvirostra; Ctenodonta, small circular species: *Whiteavesia cincinnatiensis; Lophospira abnormis.*

The Logana limestone, typically exposed in Jessamine, Woodford, and Franklin counties, Kentucky, was described in the bulletin on the Lead and Zinc bearing rocks of Central Kentucky, by Prof. Arthur M. Miller, in 1905. It appears to be approximately equivalent to the Hermitage and Saltillo limestones of Tennessee, and contains the following fauna:

Lingula modesta, Ulrich; *Lingula covingtonensis,* Hall and Whitfield; *Trematis punctostriata,* Hall; *Cryptolithus tessellatus* (= *Trinucleus concentricus*).

Of the various species listed from the Saltillo, Hermitage, or Logana limestones, the following occur at Cincinnati, Ohio, in the lower fifty feet of rock there exposed, below the Fulton layer which contains the Triarthrus becki or Utica fauna:

Prasopora simulatrix; Lingula modesta; Lingula covingtonensis; Whiteavesia cincinnatiensis; Lophospira abnormis; Cryptolithus tessellatus; Schizocrania schucherti is regarded as closely related to *Schizocrania rudis,* and *Leptobolus lepis* evidently is related to the variety found in the Saltillo limestone.

Owing to the presence of similar or identical species in the

lower 50 feet of rock exposed at Cincinnati, Ohio, and in the Saltillo, Hermitage, and Logana limestones of Tennessee and Kentucky, Dr. E. O. Ulrich is inclined to regard them all as approximately equivalent, an opinion which he finds fortified by the presence in the lower rocks at Cincinnati of various species, not here listed, which occur also in the Logana limestone.

Dystactospongia madisonensis, Foerste.

Along a branch of Laughery creek, a mile southwest of Ballstown, Indiana, the so-called shale bed, in the lower part of the Saluda section, is underlaid by four and a half feet of soft clayey material, and six feet of argillaceous rock with an abundance of *Tetradium minus* at various levels. This lower layer contains also *Rhynchotrema capax, Streptelasma vagans, Endoceras proteiforme,* the species of *Byssonychia* found at the same horizon two miles south of Versailles, and also *Dystactospongia madisonensis.* The latter was found about 2 feet from the top of this *Tetradium* section. *Dystactospongia madisonensis* occurs also in the upper part of the underlying section, a foot and a half thick, accompanied by *Calapoecia cribriformis; Tetradium minus* occurs occasionally in the lower part. The basal part of the section, nearly three feet thick, contains rather numerous large specimens of *Columnaria alveolata,* and *Strophomena planumbona. Dystactospongia madisonensis,* associated with *Calapoecia cribriformis,* and *Strophomena vetusta,* occur just below the *Tetradium* horizon also at the bridge east of Ballstown. The horizon for *Dystactospongia madisonensis,* therefor, appears to be at the base of the Saluda. The total thickness of the Saluda west of Ballstown is 56 feet. The upper half, 28 feet thick, is formed by the mottled limestone, which overlies the shale bed.

At the railroad cut west of Weisburg, only the base of the mottled limestone is exposed but here it contains numerous specimens of *Entomis madisonensis, Eurychilina, striatomarginata, Leperditia caecigena, Primitia cincinnatiensis,* and *Primitia milleri.* Beneath this level are 11 feet of clay, overlying a thin limestone layer containing *Strophomena sulcata, Streptelasma vagans* and *Streptelasma divaricans.* It is underlaid by 9 feet of limestone near the middle of which *Tetradium* occurs. The shale bed, six and a half feet thick, occurs at the base of the cut. The base of the

Saluda is not exposed. East of Weisburg, the total Liberty, with the exception of the extreme top is exposed.

Leptobolus lepis — cliftonensis, var. nov.

(Plate II, figs. 20 A,B,C.)

In the Saltillo limestone, at Clifton, Tennessee, there occurs a species of *Leptobolus* evidently closely related to *Leptobolus lepis,* Hall. Its outline is oval, or elliptical ovate, and pointed toward the beak of the pedicel valve. A sharply defined median septum extends from the anterior end of the pedicel groove forward almost to the center of the pedicel valve. This septum widens moderately, and is impressed along the median line by a sharp, narrow groove, also widening anteriorly. This results in two very narrow, subparallel grooves in the cast of this valve. The muscular impressions on each side of this median septum are limited anteriorly by a thickening of the interior of the shell which extends from the anterior end of the median septum laterally across the valve. Only a single narrow septal ridge is seen in the interior of a brachial valve, and this follows the median line of the shell to within a quarter of the length of the shell from its anterior edge.

No trace of lateral septal ridges was found in the brachial valves, and the septal ridges of the pedicel valve were not strongly divergent as in the specimens of *Leptobolus lepis* figured by Hall and Clarke. The Tennessee specimens agree more with figures 5 and 6, on plate 3, *New York Paleontology*, vol. VIII, figured by Hall and Clarke from Covington, Kentucky. But in the Tennessee specimens, the septal ridges and intermediate groove of the pedicel valve extend as far as the pedicel cavity, and are less divergent anteriorly. The color of the Tennessee specimens varies from dark brown to whitish, assuming the latter color in the coarser grained limestone layers which are interbedded with the finer grained limestones prevailing in the Saltillo bed.

If the figures presented by Hall and Clarke are correct in the details here mentioned, the Tennessee specimens are sufficiently distinct to merit at least a varietal designation.

A pedicel valve from the Fulton layer, west of Brent, Kentucky, agrees with figure 5, on plate 3.*New York Paleontology,* vol. VIII, in having the two septal ridges with the intermediate depression confined to the anterior part of the muscular area. The

posterior part of this area, toward the pedicel groove, is smooth along the median part. The Tennessee specimens come from a much lower horizon.

Lingula modesta, Ulrich.

(Plate II, fig. 17.)

The type specimens of *Lingula modesta* were obtained from the Logana bed, at Frankfort, Kentucky. They are distinguished by their flatness, and the almost obsolete concentric striae. Specimens occasionally attain a length of 14 mm., and a width of 9 mm. In the larger specimens the lateral outline is gently convex, rounding moderately toward the beak, and more abruptly toward the anterior margin. This results in a form of outline which might be described as quadrangular ovate, in the case of the larger specimens.

Lingula covingtonensis, Hall and Whitfield.

(Plate V, figs. 5, 6.)

Lingula covingtonensis (fig. 5) was described from that part of the section at Covington, Kentucky, which lies between 25 and 50 feet above low water in the Ohio river. It is characterized by its elliptical form, the posterior extremity, at first sight, appearing almost equally rounded compared with the anterior. As a matter of fact, however, the rounding is more abrupt at the beak. The concentric striae are sharp and rather distant.

Lingula cobourgensis, as figured by Billings, is similar in form, though possibly slightly more elongate. Judging from the description, the concentric striae are fine and sharply elevated on each side of the beak, but more like fine concentric undulations of growth elsewhere. If that be a constant feature, *Lingula covingtonensis* differs in the sharpness of the concentric striae over the general body of the shell.

Specimens, identified as *Lingula covingtonensis,* occur in the Logana bed, at Frankfort, Kentucky (fig. 6). They agree in outline, and are characterized by the fine, sharp, rather distant concentric striae. The shell substance is whitish. In some of the specimens, the interior surface of the valves is irregularly pitted, the pits being arranged approximately parallel to the concentric mark-

ings belonging to the exterior. In these specimens, the concentric striae on the exterior are fine, sharp, and rather distant, as in other specimens from the same locality, also identified as *Lingula covingtonensis.*

Specimens pitted interiorly were described by Ulrich, from the strata a few feet above low water mark, at Covington, Kentucky, as *Lingula whitfieldi.* In the latter, however, the shell is stated to be relatively shorter, and broader in front, and the concentric striae are described as rather irregular and never so regularly disposed.

The type of *Lingula covingtonensis,* numbered 139 in the James collection at Chicago University, 12.6 mm. long and 10 mm. wide, is characterized by strong and rather equidistant concentric striae, between which the remaining concentric striae are much less conspicuous. It is preserved in a fine-grained limestone, the lower half of which is full of a small form of *Dalmanella* resembling *Dalmanella multisecta.* It evidently was obtained from the limestones several feet below the two-foot crinoidal layer which immediately underlies the Fulton horizon.

Lingula waynesboroensis, sp. nov.

(Plate II, fig. 18; Plate V, fig. 7.)

Three and a half miles northwest of Waynesboro, Tennessee, near the home of W. D. Helton on Beech creek, a species of *Lingula* occurs in the Saltillo limestone, closely resembling *Lingula briseis,* Billings, and *Lingula procteri,* Ulrich, in outline. The same species occurs also in the Saltillo bed, at Clifton, Tennessee.

The shell substance of this Tennessee species is white. The shell is very thin. The lateral outline is gently convex or subparallel anteriorly, converging gradually posteriorly toward the beak. Anteriorly, the lateral outline rounds into the anterior margin, and, the latter being less strongly convex, the outline of the shell is more oblong than oval. Concentric striae, very fine, and numerous, are separated by flat interspaces which usually are several times as wide as the striae, at least along the middle part of the shell, anteriorly. Radiating striae are usually absent, although extremely fine radiating striae may be noted occasionally. The interiors of pedicel valve occasionally have a low, broad septal elevation, extending slightly beyond the center of the shell; anteriorly, this

elevation attains a width of about half a millimeter. A much narrower septal ridge occurs rarely in the brachial valve. In most of the specimens, no trace of these septal ridges was noticed. No other markings are shown by the interiors of the specimens at hand. Length, 13 mm.; width, 8.7 mm.

In *Lingula briseis*, Billings, the very fine longitudinal striae are characteristic, while the concentric markings are obscure. In *Lingula waynesboroenis*, the conditions are reversed.

Lingula procteri, Ulrich, is a larger and much thicker shell. It is much more robust in every way, and as a result the markings of the interiors of the valves are much better preserved, and in greater detail. Only concentric striae and more distant undulations of growth are mentioned in the original description, but obscure longitudinal markings appear to be present also, judging from the illustrations by Hall and Clarke. The outline of the shell also is more oval.

Orthorhynchula linneyi, James.

(Plate III, fig. 10.)

This species was described by U. P. James from specimens obtained by W. M. Linney in the Fairmount beds of Boyle county, Kentucky. It was listed from this horizon by W. M. Linney, in 1882, in his reports on Garrard, Lincoln, and Washington counties, and in his *Notes on the Rocks of Central Kentucky.* In his report on Clarke county, in 1884, Linney lists this species both from the Fairmount beds and from the Greendale division of the Cynthiana formation.

At the upper Fairmount horizon, *Orthorhynchula linneyi* is associated with *Escharopora hilli*, and *Cyrtoceras vallandinghami*. *Strophomena maysvillensis* occurs, although the chief horizon for this species is at the base of the Fairmount. An early variety of *Platystrophia ponderosa* also is found. Among other species may be mentioned: *Escharopora falciformis, Constellaria florida,* and *Phylloporina clathrata.*

Orthorhynchula linneyi is common in the upper Fairmount about a mile north of Paint Lick, in the southwestern corner of Madison county. It is abundant also at the bridge south of Redhouse station, in the northern part of this county; and about three miles west of Richmond, near the home of W. H. Parks. Three

miles east of Junction City, half a mile from Givens station, near the northwestern edge of Lincoln county, it is less abundant. Several specimens are said to have been found by W. T. Knott about three miles southeast of Lebanon, on a branch of Caney creek, about a mile and a half north of the Lebanon-Bradfordsville road, south of the home of Richard D. Murrell. Since *Strophomena maysvillensis* is quite common in the lower part of this exposure, the specimens must have been obtained from the Fairmount.

Orthorhynchula linneyi is a characteristic member of the southern Fairmount fauna. It does not appear to occur north of a line connecting Clark with Washington and Marion counties, unless possibly as occasional, very rare specimens. Southward, however, it is very abundant. In southern Kentucky, along the Cumberland river, *Orthorhynchula linneyi* occurs in the Fairmount bed about two miles east of Rowena. Specimens of *Labechia ohioensis* occur 14 feet above the river. Small specimens of *Labechia ohioensis* and *Tetradium minus* occur 19 feet above the river. Both species are represented by good specimens 35 feet above the river. The intermediate strata, between 20 and 35 feet above the river, consist of limestone layers, 3 to 4 inches thick, interbedded with equal thicknesses of clayey layers, both richly fossiliferous. In these layers *Orthorhynchula linneyi* occurs associated with *Constellaria florida.* Farther up the river, sandy, strongly cross-bedded limestones occur below the horizons containing *Labechia* and *Tetradium.*

This association of *Orthorhynchula linneyi* with *Labechia* and *Tetradium,* in southern Kentucky, is characteristic of the upper Fairmount also in the area covered by the Columbia folio, in Tennessee. The lower Fairmount here is represented by richly fossiliferous strata containing *Strophomena maysvillensis.*

Orthorhynchula linneyi has been listed by Bassler also from the vicinity of Ben Hur, in the Powell Valley, in the southwestern corner of Virginia. Here it occurs in strata equivalent to the Fairmount, associated with *Platystrophia ponderosa* and *Modiolopsis modiolaris.*

Orthorhynchula linneyi is abundant also in the Cynthiana formation of Kentucky. Linney mentions it at this horizon in his report on Clark county. It is very abundant in Nicholas county, along the railroad between Pleasant Valley and Millersburg, and it occurs also at the Lower Blue Lick Springs. Specimens are very rare along

the railroad between half a mile and two miles east of Colby, west of Winchester, in Clark county. Near Lexington and Versailles, specimens are rather common at some localities. It is abundant also along the path leading to the old reservoir southwest of Frankfort.

North of a line connecting Nicholas and Franklin counties, *Orthorhynchula linneyi* is very rare. In fact, it is very rare even in Scott and Harrison counties. A single well preserved specimen was found at railroad level at the base of the quarry west of Ivor, opposite Moscow, on the Ohio river. Another was found 10 feet above the railroad at the quarry east of Carnestown, about two miles farther up the river. It is very rare also at some localities in central Kentucky, for instance, along the railroad between the tunnel west of Million and Valley View, in Madison county.

In Tennessee, *Orthorhynchula linneyi* occurs in the Catheys formation to which the Cynthiana formation of Kentucky is essentially an exact equivalent. The underlying Bigby formation of Tennessee has been divided into two members in Kentucky. The upper member, in which *Hebertella frankfortensis* is common, is called the Paris member. The lower member, in which *Prasopora simulatrix* is common, is called the Wilmore member. As a matter of fact, *Hebertella frankfortensis* occurs also in the Wilmore bed, and a species of *Prasopora* closely similar to *Prasopora simulatrix* occurs in the Paris member, so that these two members are not well differentiated. The Logana bed of Kentucky is the Hermitage of Tennessee.

In Woodford county, Kentucky, one mile southeast of McKee ferry, and two miles south of the Crow distillery on Glenn creek, east of the road, near the home of Allen McGarvey, on the farm owned by Mrs. Ben Williams, *Orthorhynchula linneyi* is found in a very hard, fine grained, blue limestone below the Greendale member of the Cynthiana formation. This fine-grained limestone is regarded as the northern extension of the Perryville bed. In addition to *Orthorhynchula linneyi* it contains *Hebertella parksensis, Lophospira medialis, Lophospira bowdeni, Loxoceras milleri,* and *Isochilina jonesi.* This appears to be the Dove limestone of Safford's section at Nashville, Tennessee.

Whenever a species occurs at two horizons separated by a considerable interval, it is possible usually to detect at least some slight difference between the two sets of forms, representing the amount of change undergone by the species during the lapse of time

represented by the interval. In the case of *Orthorhynchula linneyi,* a larger number of the Fairmount specimens have a more globose form, due to a less angular junction of the valves along the lateral margin, but more globose and more angular forms may be noticed at both horizons. The normal number of plications on the fold is four, but in the specimens from the Greendale division of the Cynthiana formation, at Pleasant Valley, the number is increased not infrequently, by intercalation, to five or six.

The muscular scar of the pedicel valve has a quadrate appearance due the parallel lateral outlines produced by the internal thickening of the shell on each side. It is of fairly large size. In a specimen having a length of 22 mm., the muscular scar had a width of 8 mm. and a length of 11 mm. The interior outline of the scar usually is moderately convex but may be nearly straight.

Rhynchotrema dentata — arnheimensis.

(Plate III, fig. 13.)

Rhynchotrema dentata-arnheimensis was found loose at the Arnheim horizon, a quarter of a mile east of Andersonville, and in situ at the same horizon half a mile south of Arnheim, and a mile and a half south of Russellville; all in Brown county, Ohio. In Kentucky, it occurs three miles south of Maysville; also at the Brown's run school house, two miles northeast of Rectorville and 8 miles southeast of Maysville; at the foot of the hill east of Wyoming, 30 miles south of Maysville; about a third of a mile southwest of Sunset, on the road to Day's mill; half a mile southwest of Howard mill, on the road over the hill to Spencer; a mile south of Indian Fields, and then two miles west, at the Curry bridge across Howard creek; four miles north of Richmond, at the railroad cut north of Ophelia; a mile north of Rowland, on the west side of Logan creek; near the Pleasant Valley church, southwest of Rush Branch post office; three miles southeast of Lebanon, a mile south of the home of P. L. Mudd, along a branch entering Caney creek from the east; a mile west of Lebanon, northwest of the home of Col. J. B. Wathen; half a mile north High Grove; a mile south of Smithville; near the home of J. D. Stansbury, a mile and a half south of Mount Washington; four miles southeast of Jeffersontown, where the road descends abruptly toward Floyd creek, a mile east of Shinks branch; three quarters of a mile west

of Fisherville and immediately south of Clay Village, at the northern foot of Jeptha Knob. At Jeptha Knob, this variety of *Rhynchotrema* occurs 945 feet above sea level, associated with *Platystrophia ponderosa*. At 985 feet *Dalmanella multisecta* is common, indicating a fault equivalent to the entire thickness of the Maysville formation. At Madison, Indiana, a single specimen of *Rhynchotrema dentata-arnheimensis* was found years ago by Mr. John Hammell, at the Arnheim horizon. So far, no specimens have been found in the Arnheim north of Madison, Indiana, or Andersonville, Ohio. Southward, in Tennessee, however, they occur at Goodlettsville, Newsom, and Clifton.

The horizon for *Rhynchotrema dentata-arnheimensis* is near the middle of the Arnheim bed, associated with *Dinorthis carleyi,* and above the *Leptaena richmondensis-precursor* horizon. At Madison, Indiana, *Platystrophia ponderosa* occurs near the lower end of the first railroad cut. *Leptaena richmondensis-precursor* is found 7.5 feet farther up. *Dinorthis carleyi* makes its appearance 4 feet above the latter, and is rather common for a distance of a foot and a half. The interval between the *Dinorthis carleyi* horizon and the top of the culvert at the upper end of the cut is 30 feet. At Arnheim, the lowest specimens of *Leptaena* occur 5 feet above the *Platystrophia ponderosa* layer. The vertical range of the *Leptaena* is three feet nine inches. *Rhynchotrema* occurs in the upper six inches of the *Leptaena* horizon, and is overlaid by the *Dinorthis carleyi* layer.

The strata containing *Leptaena richmondensis-precursor, Rhynchotrema dentata-arnheimensis*, and *Dinorthis carleyi* inaugurate a new fauna. They are the first representatives of the Richmond fauna among the brachiopods. From this horizon upward, the rocks usually are much more richly fossiliferous than those beneath, especially those beneath the *Platystrophia ponderosa* horizon. This is true especially southward and on the eastern side of the Cincinnati geanticline, in Mason, Fleming, and Bath counties. At Maysville, the upper, fossiliferous division of the Arnheim bed is 26 feet thick, the comparatively unfossiliferous argillaceous limestone layers beneath having a thickness of 16 feet. The latter represent an ingression of muddy sediments, similar to the later ingressions resulting in the formation of the Saluda and Elkhorn beds. For these, comparatively unfossiliferous argillaceous limestones, forming the lower half of the Arnheim section, as formerly

defined, the term Sunset bed has been selected. This bed is well exposed southwest of Sunset, in Fleming county, on the road to Day's Mill. It contains occasional specimens of *Platystrophia ponderosa.* It is well exposed also at Wyoming, in Fleming county, where the base of the immediately overlying fossiliferous section contains *Leptaena richmondensis-precursor,* and *Rhynchotrema dentata-arnheimensis.*

Rhynchotrema dentata, Hall.

(Plate II, fig. 16; Plate III, fig. 12.)

Rhynochotrema dentata, as represented in the upper part of the Whitewater bed, at Richmond, Indiana (plate III, fig. 12), is characterized by the greater convexity of both valves. The middle part of the pedicel valve usually is not flattened and then partly reflexed toward the anterolateral angles, as is more frequently the case in large specimens of the Arnheim variety.

Zygospira modesta, Hall.

(Plate II, fig. 15 A,B.)

The type specimen, numbered 1356-1, preserved in the American Museum of Natural History in New York City, is 7.8 mm. long, 9.2 mm. wide, and 4.1 mm. thick. The pedicel valve has 18 distinct plications, and two indistinct ones, the latter being near the hinge margin. The four median plications are moderately elevated above the general convexity of the shell, and form a rather low, median elevation. The groove along the median line of this elevation is conspicuously wider than the two adjacent grooves. Corresponding to the median groove, the brachial valve has a comparatively strong median plication, while the two adjacent plications, one on each side, are distinctly narrower. A broad, but comparatively shallow depression extends from near the beak to the anterior margin of the shell; its lateral borders are not sharply defined but are formed approximately by the third plication on each side of the median plication. The specimen evidently was found in Cincinnatian rocks; it is labelled as coming from Cincinnati, Ohio, but this may mean merely that the specimen was obtained from some Cincinnati collection.

Similar specimens are found in the Fairmount bed at Cincin-

nati, and Hamilton, Ohio, and I have assumed the Fairmount as the type horizon.

The characteristic features of *Zygospira modesta* consist in the low median fold, and in the rather numerous lateral plications, all of them primary. In the type specimen there are 7 of these lateral plications on each side, but this number is frequently 8, and sometimes 9. Some of these specimens attain a length of 10 mm.

Zygospira cincinnatiensis, Meek.

(Plate VI, figs. 16 A, B.)

Zygospira cincinnatiensis was described by Meek as coming from an elevation of 250 feet above low water in the Ohio river, at Cincinnati, Ohio. *Strophomena planoconvexa, Dalmanella (Bathycoelia) bellula, Cyclocoelia ella* (= *sordida*), and *Plectorthis plicatella* are listed from 300 feet above the Ohio river. *Dalmanella multisecta* is said to range upward about 200 feet above low-water mark of the Ohio, and *Platystrophia laticosta*, probably including the form here described as *Platystrophia profundosulcata-hopensis*, is listed as coming from 250 to 300 feet above low-water in the Ohio. This suggests the Mount Hope bed for the origin of the type specimens of *Zygospira cincinnatiensis* as described by Meek. Unfortunately, the type specimen figured by Meek can no longer be found, and the series of specimens in the James collection at Chicago University numbered 164, and there labelled as types, evidently are from the upper Fairmount. In view of the fact that Meek's specimens were obtained from James, and considering the large size of the specimens studied and the more frequent disposition of the plications to bifurcate, as noted in the original description, it seems more likely that the specimens received by Meek were from the type series, and therefore also from the Fairmount. At the time James made his early collections, the horizons of many fossils was not known with the accuracy now considered desirable.

The specimens from the upper Fairmount, which are here regarded as typical, are distinguished from *Zygospira modesta* by the smaller number of primary lateral plications, usually 5 on each side of the median fold. In consequence the plications appear larger, more angular, and more distant from each other. The more prominent median elevation on the pedicel valve is due chiefly to the larger size of the individuals. The four primary plications on

the median fold and the intermediate grooves have very much the same appearance as in *Zygospira modesta.* While the bifurcation of the primary plications, or the intercalation of additional ones, is the chief character usually relied upon in diagnosing this species, too much weight must not be given to this feature, since it is not constant, and numerous specimens may be collected at the typical horizon, in which there is no evidence of bifurcation. Among the four primary plications on the median fold, it is the lateral plications, and not the two median plications which frequently are bifurcated. Bifurcation of one or two of the lateral plications on each side of the median fold is not rare. Occasionally, even the two median plications on the fold are bifurcated toward the anterior margin of the shell, or one or two small plications are inserted near the anterior end of the median groove. Some of these specimens attain a length of 13 mm. Only the larger specimens are likely to show evidence of frequent bifurcation.

Although only a part of the specimens in the upper Fairmount show evidences of bifurcation it should be stated that it is only at this horizon that bifurcation becomes conspicuous. In the Mount Hope bed, at Cincinnati, Ohio, Vevay, Indiana, and a mile north of Mason, Kentucky, specimens occur with only 5 broad, angular, lateral plications, and with a prominent fold and distinct, broad sinus, but with no bifurcation of the plications. These specimens undoubtedly are the ancestral forms of typical *Zygospira cincinnatiensis* from the upper Fairmount. The type, however, originated already in the middle Eden, where specimens with 5 broad, angular lateral plications are found locally, for instance at Vevay, Indiana.

Catazyga uphami — australis, var. nov.

(Plate II, figs. 19 A,B; Plate III, figs. 14, A,B,C.)

In the Camp-nelson division of the High-bridge formation, at High Bridge, Kentucky, there is a species of *Catazyga* evidently closely related to *Catazyga uphami*, described from a somewhat higher horizon, in Minnesota. In Kentucky, this species of *Catazyga* is associated with *Orthis tricenaria, Hebertella bellarugosa,* and *Rafinesquina minnesotensis.*

The *Catazyga* from High Bridge, Kentucky, agrees with the typical form of *Catazyga uphami* in the number of radiating plica-

tions, about 60 on each valve. Since the intercalation of plications among those which may be regarded as primary is almost confined to the posterior third of the shell, it is evident that it is not the larger size of this shell, compared with *Zygospira recurvirostra,* which gives this *Catazyga* the appearance of having more plications than the latter species. Compared with typical *Catazyga uphami,* the specimens from High Bridge are broader, less elongate anteriorly, with a broad shallow depression on the anterior half of the pedicel valve, and a corresponding low elevation on the brachial valve. Since the absence of the sinus in the pedicel valve is characteristic of typical *Catazyga uphami,* the specimens from High Bridge may be regarded at least as a variety.

Catazyga headi — schuchertana, Ulrich.

(Plate II, fig. 3; Plate III, figs. 11 A, B, C.)

Catazyga headi was described by Billings from loose blocks of limestone, more or less erratic, found on the south side of the St. Lawrence river, opposite Three Rivers, seventy miles southwest of Quebec. The types described by Billings no longer can be identified among the material preserved in the Museum of the Canadian Geological Survey, but specimens collected by Whiteaves from the type locality are at hand and may be regarded as replacing the types. These specimens present the following characteristics.

Beak of pedicel valve slightly compressed laterally, the compression extending anteriorly as a faint elevation, the sides of which diverge at angles of about 12 degrees with the median line. Anterior to the center of the valve, the median part of this faint elevation is slightly depressed, forming a very faint and rather broad median depression. The brachial valve has a very faint median depression near the beak. Toward the anterior part of the valve there may be a faint median depression, a faint elevation, or neither, showing that these features can not be regarded as specific characteristics. The general appearance of the shell is well represented by the figures accompanying the original description. The lateral outline varies. The lateral outline usually is slightly straightened, even in the broadest specimens, but some specimens are distinctly compressed laterally, and then have a distinctly elongate appearance, resembling the form figured by Billings as variety *borealis.* With an abundance of material at hand, it appears impos-

sible to distinguish these extremes of form as distinct species, or even as varieties. As a matter of fact, within certain limits, the species varies considerably in form at the same locality, in the same strata. At a distance of about 12 mm. from the beak there are about 7 radiating striae in a width of 3 mm.

Catazyga headi is represented along the northern line of outcrop of Cincinnatian strata, in Ohio, Indiana, and northern Kentucky, by a closely similar form. For this form, Mr. E. O. Ulrich proposed the name *Glassia schuchertana,* in the *American Geologist,* vol. 1, p. 186, in 1888, and added the following comments:

This name is proposed for the shell figured and described by Meek in volume 1, *Ohio Paleontology,* page 127, plate XI, figures 1a-1d, under the name *Zygospira Headi,* Billings (sp.). Recent investigations of excellent material, belonging to Mr. Charles Schuchert's extensive collection of paleozoic brachiopods, show that our shell is distinct from the Canadian form, and that it possesses internal spires arranged precisely as in Davidson's new genus *Glassia.* Some of the specimens show further that the radiating striae which usually mark the surface are often very obscure and in rare cases entirely absent. Such smooth examples were collected near Versailles, Indiana.

Numerous specimens collected since the preceding lines were published indicate that well preserved specimens are not smooth but are covered with radiating lines which may be traced as far as the tip of the beak, as is also the case in typical specimens of *Catazyga headi* from the type locality in Canada. Smoothness results from weathering or exfoliation, and usually is noticed only in small specimens or toward the beak of larger specimens, although, occasionally, specimens 15 mm. in length which have been more or less weathered or exfoliated appear smooth until held transversely to the direction of some strong beam of light.

Specimens from Cincinnatian areas vary considerably in outline, as is true also in case of the specimens from Canada. Some are broad and some are narrow, resembling typical *Catazyga headi* and its variety *borealis,* as illustrated by the Ohio specimens figured by Hall and Clarke, but these forms are always intermingled in the same strata and can scarcely be said to represent even varieties. The subquadrate appearance of the shell, when seen from the brachial side, is due chiefly to the considerable lateral extension of the hingeline, and this is noticed even in the more narrow forms. The comparative straightening of the lateral outlines is shown chiefly by the broader specimens, but this is not a constant feature.

In attempting to distinguish between the Cincinnatian specimens

and the typical specimens from Canada, the absence of a broad, though very shallow median depression along the anterior part of the pedicel valve of the Cincinnatian specimens has been seized upon. In addition to this, attention is called again to the tendency toward a subquadrate outline in case of the brachial valve, at least posteriorly, owing to the considerable lateral extension of the hinge-line. If these features do not prove comparatively constant for the Cincinnatian specimens, all attempt to distinguish them under a separate designation may prove of little value.

The internal markings, as might have been suspected, are closely similar to those of *Catazyga erratica.* The hinge-plate of the brachial valve consists of two stout processes separated by a sharp, narrow cleft, from each side of which the crural bases extend straight forward, separated by a distance of one millimeter at a distance of 2 mm. from their points of attachment. A low, flat median elevation extends forward, becoming tripartite at a distance of about 4 or 5 mm. from the beak, the middle division being longer, more narrow, and sharper. Exterior to each of the lateral divisions, an additional parallel low elevation is present. A short distance anterior to the pedicel cavity of the pedicel valve, a sharp, narrow median groove starts forward across the muscular area. On each side, posteriorly, there is a low elevation, broadening and thickening along the middle of the muscular area, narrowing again abruptly anteriorly, and bordered laterally at their distal extremities by a distinct and rather narrow depression. The thickening of the shell in the region of the muscular area terminates abruptly across the center of the valve. It is crossed by several radiate lines not mentioned in the preceding description.

The chief horizon for the Cincinnatian specimens of *Catazyga headi* is at the lower *Hebertella insculpta* horizon, at the base of the upper, or Blanchester division of the Waynesville bed, and in the immediately overlying and underlying strata. It is found at the base of the Blanchester division, immediately above *Hebertella insculpta,* along the creek a mile west of Blanchester, Ohio, and also a mile northeast of Woodville, along Stony creek, about three miles south of the Blanchester locality. It is common immediately above *Hebertella insculpta* in Adams county, Ohio, along a road crossing Eagle creek, a short distance south of the mouth of Gordon run, and at about the same horizon along a road crossing Suck run, three and a half miles southwest of Bentonville, a mile east of the Suck run

school house. A single loose specimen of *Catazyga headi* was found east of Concord, in Lewis county, Kentucky. Several specimens have been found loose directly east of Wyoming, along the southwestern edge of Fleming county. At both of these Kentuckian exposures the specimens were found at the level of the middle, or Clarksville division of the Waynesville bed, but may easily have dropped from the base of the Blanchester division.

Along Sewell run, immediately south of the pike from Clarksville to Wilmington, in Clinton county, Ohio, Dr. George M. Austin found a considerable number of specimens from 6 to 10 feet below the lower *Hebertella insculpta* horizon, in the upper part of the Clarksville division. Along Stony Hollow, northwest of Clarksville, *Catazyga headi* occurs within two feet of the base of the lower *Hebertella insculpta* horizon, and a loose specimen occurred ten feet below this base. Hall and Clarke figure a specimen from the vicinity of Waynesville, Ohio. The species figured by Meek in the *Ohio Paleontology*, vol. 1, probably came from Clinton county.

Catazyga headi is listed from Richmond, Indiana, and probably was obtained a considerable distance down the river from this city. It occurs north of Versailles, being listed as *Glassia schuchertana* from this locality. At Madison, Indiana, *Catazyga headi* occurs along the Hitz road, directly west of the great railroad cut, 77 feet below the great *Columnaria* reef, here forming the base of the Saluda bed. Since the upper *Hebertella insculpta* layer, at the top of the Waynesville bed, occurs along the Michigan road 32 feet below this *Columnaria* layer, *Catazyga headi* must belong about 45 feet below the upper *Hebertella insculpta* layer. Since the Blanchester division of the Waynesville bed is not known to exceed 20 feet in thickness at Canaan and at Moores Hill, Indiana, it seems probable that at Madison *Catazyga headi* occurs in the upper part of the Clarksville division.

Judging from the preceding notes, *Catazyga headi* occurs in the upper part of the middle or Clarksville division of the Waynesville bed, and at the base of the upper or Blanchester division. In its geographical distribution, its range appears nearly coterminous with the area within which *Strophomena neglecta*, the most widely distributed fossil characteristic of the Blanchester division, has been recognized. It has not been found, so far, south of Wyoming, Kentucky, and Madison, Indiana.

Cyclocoelia sordida, Hall.

(Plate II, fig. 10; Plate VI, fig. 8 A, B.)

The type of *Cyclocoelia sordida,* Hall, (plate II, fig. 10,) preserved in the American Museum of Natural History, in New York City, possesses 21 primary plications and one secondary plication. The length of the specimen is 8.2 mm. and the thickness through the valves is about 4 mm.

The original description of *Cyclocoelia ella, Hall,* (plate II, fig. 11,) mentions 15 to 20 simple plications, but the first published illustrations of this species, in the *Fifteenth Report* of the New York State Cabinet of Natural History, plate 2, fig. 6, represents a specimen with at least 27 or 28 plications, and figure 7 represents a specimen with about 22 plications. Among the specimens preserved in the American Museum of Natural History in New York City, and numbered 1056-3, one specimen has 27 plications of which between 5 and 7 are intercalated within one millimeter of the beak; a second specimen has 21 plications; and three other specimens have 18 and 19 plications. *Cyclocoelia ella* is identical with *Cyclocoelia sordida.*

The specimens with 29 to 34 plications (plate VI, figs. 6 A, B, C, D, and 7 A, B, C, D) usually begin with about 21 primary plications, as in typical *Cyclocoelia sordida,* but the number of plications is increased by intercalation. These forms, here called *Cyclocoelia sordida-multiplicata,* appear intermediate between *Cyclocoelia sordida* and *Cyclocoelia sectostriata,* but the plications of the latter species appear more angular.

Cyclocoelia crassiplicata, sp. nov.

(Plate III, 16 A,B,C; Plate VI, figs. 9 A-C and 10 A-C.)

Among the specimens of *Cyclocoelia* found in the Fairmount bed at Cincinnati, Ohio, occurs a species, which is usually identified as *Cyclocoelia ella.* It possesses usually between 11 and 15 primary plications with occasionally several additional secondary plications, but the chief characteristic of this species consists not so much in the smaller number of plications as in their much greater prominence and angularity. This is especially noticeable in specimen possessing 18 plications, prominent and angular, while in a specimen of *Cyclocoelia ella* with only 18 plications, the latter are

low, as in ordinary specimens of that species. Since the contrast between the two species consists chiefly in the much greater prominence of the plications in *Cyclocoelia crassiplicata*, the difference is much greater to the eye than indicated by the accompanying illustrations.

Cyclocoelia sectostriata, Ulrich.

(Plate III, figs. 15 A, B.)

Cyclocoelia sectostriata, Ulrich is something more than a multiplicate form of *Cyclocoelia ella*. About 21 plications originate sufficiently near the beak to be called primary. An approximately equal number is intercalated within 3 mm. of the beak, so as usually to alternate with the latter, and additional plications are intercalated anteriorly, bringing the total number up to about 50 in a specimen 8 mm. in length. The type, 10 mm. in length, was described as possessing 30 to 35 primary plications increasing to about 70 at the margin. Specimens of this type occur in the upper Fairmount. The specimen represented by figure 21, on plate 7, of the *Twentyfourth Report* on the New York State Cabinet of Natural History may belong here. The original specimen is preserved in the Dyer collection in the Museum of Comparative Zoology, at Harvard University, and is well represented by the published figure. The prominence of several of the median plications of the brachial valve may be an individual characteristic. The chief difference consists in the absence of additional intercalated plications toward the margin of the shell.

Trematis punctostriata, Hall.

(Plate V, fig. 1.)

Shell large, attaining a width of 30 mm.; nearly circular, width a little greater than the length. Brachial valve moderately convex, the convexity increasing toward the beak. Shell pitted, the pits arranged in radiating rows. Along the anterior half of the shell, and laterally, the pits are larger, and the rows are closer together. Eight to eleven rows occupy a width of two millimeters. The rows evidently increase by intercalation. Posteriorly, especially along the umbonal part of the shell, the radiating rows are more distant, and appear like narrow grooves crossing an other-

wise comparatively flat surface. Each of these grooves is formed by a series of pits distinctly smaller than those on the anterior half of the shell. The distance from the beak at which the arrangement of pits in comparatively distant rows gradually merges into the arrangement in closely contiguous rows varies in different specimens. In some specimens, the rows become contiguous within 8 mm. from the beak; in others they remain distant even at 13 mm. from the beak. The type, figured by Hall and Clarke, was only a young specimen.

The type was found in the Saltillo limestone at Clifton, Tennessee, a short distance south of the Landing. Similar specimens occur in the Logana limestone at Frankfort, Kentucky. Both of these horizons are regarded as identical with the Hermitage of the area covered by the Columbia folio, in Tennessee.

Trematis ottawaensis, Billings is figured as having rows of pits in close juxtaposition even in the umbonal area toward the beak. There is no indication of flat interspaces on the posterior half of the shell. Shells of this type, I have not seen either in Kentucky or in Tennessee.

Trematis fragilis, Ulrich.

(Plate V, figs. 3, 4, 2.)

Trematis fragilis was described by Ulrich from the lowest beds of the Cincinnati group, a few miles south of Covington, on Bank Lick creek, Kentucky. According to Nickles, this places its horizon in the strata beneath the Fulton layer, in the argillaceous strata near the base of the section. Its chief characteristic is the limitation of the radiate lines of minute pits to the posterior part of the shell, chiefly posterior to a line crossing the shell transversely at the beak, although, in case of the pedicel valve, these rows of pits may be detected also for a short distance anterior to the foramen. These pits are too small to be detected without the aid of a lens. The shell, in general, appears smooth, modified in the case of the upper valve by wrinkles, some of them concentric, which may be due in part to vertical compression of the shell which usually is preserved in an argillaceous matrix. The shell of both valves is very thin, and the traces of original concentric markings usually are faint. The outline of the shell is nearly circular, slightly wider than long, and the upper valve is only moderately

convex. The concavity of the cardinal slopes suggests that the beak was formerly distinctly elevated above the plane of the lower valve. The radiate lines of minute pits are separated by relatively wide, flat interspaces. The foraminal depression was 2.5 mm. long in a specimen having a length of 17 mm., but 24 mm. is mentioned as the average length of the shell. (plate v, figs. 3, 4.).

The specimen from which figure 8 on plate 1, of vol. 2 of the beak and along the margin of the shell almost as far as the anterior *Ohio Paleontology* was prepared is preserved in the American Museum of Natural History, in New York City. It is numbered 1335-2, and was identified by Hall and Whitfield provisionally with *Trematic punctostriata.* The punctae are very minute and can be recognized only under a lens. The punctae are distinct at the edge, but are absent from the greater part of the shell, forming the central and surrounding parts of the valve. Compared with the figure in the Ohio Paleontology, the rows of punctae are closer together, and the anterior outline of the shell is more rounded, and not straightened as figured, although wider than long. This specimen was referred by Ulrich to his *Trematis oblata,* in his original description of that species, possibly on the basis of the illustration in the Ohio Paleontology.

The specimen from which figure 9 on plate 1 of vol. 2 of the *Ohio Paleontology* was prepared and here illustrated by fig. 2 on plate v, forms No. 102 of the James Collection, at Chicago University. Its length is 15 mm. and its width is 15.2 mm. The foraminal depression is almost 3 mm. in length, and is V-shaped in form at its origin. The concentric striations are faint. The pits are minute, and are arranged in rows separated by relatively wide interspaces. They are restricted to the area posterior to a line running transversely across the shell at the anterior end of the pedicel notch. This specimen is regarded as belonging to *Trematis fragilis,* although it is not known from what horizon it was obtained.

Possibly the specimen represented by figure 8 in the *Ohio Paleontology,* described above, also may belong to *Trematis fragilis.* In *Trematis oblata* the pits become larger anteriorly, along the margin, and approach each other sufficiently to form a network; moreover, the shell has a distinctly ovate outline, the sides rounding rather abruptly into the anterior outline of the shell, which is distinctly less convex or even nearly straight.

Schizocrania rudis, Hall.

(Plate III, figs. 22 A, B.)

The type of *Schizocrania rudis* was found in the Saltillo limestone at Clifton, Tennessee. Its length was a little over 8 mm., and its width was about 13 mm. Judging from the illustration accompanying the original description, the specimen was imperfect posteriorly, and was flattened out laterally. The radiating striae are described as sharp, and flexuose.

In a second specimen, found by the writer at the same locality, the posterior outline on one side of the beak is well preserved, and is shown not to be concave, but rounded as in oval forms of *Schizocrania filosa,* and the beak is considerably more prominent than in that species. The length of the specimen is 11 mm., the width is 10 mm., and the number of radiating striations varies from 6 to 8 in a width of 2 mm. The striae are not flexuose except where affected by the distortion of the specimen, due to crushing. The fuller, more prominent beak, and the more conspicuous and more distant radiating striae will serve to distinguish this species from *Schizocrania filosa.*

Schizocrania schucherti, Hall and Clarke, from strata beneath the Fulton horizon at Covington, Kentucky, may prove to be much more closely related to *Schizocrania rudis* than suspected at the time when the posterior margin of the shell was believed to be concave on each side of the beak. According to E. O. Ulrich, this lower horizon at Cincinnati contains a fauna including elements closely similar to that of the Hermitage in Tennessee, to which the Saltillo limestone appears to be equivalent.

Schizocrania filosa, Hall.

Schizocrania filosa was described from the Trenton, at Middleville, New York, and the figures accompanying the original description are circular in outline. A specimen from the Trenton at Trenton Falls, New York, is figured by Hall and Clarke as oval in form.

On the south side of the Kentucky river, in Madison county, opposite Ford, the top of the Paris division of the Lexington limestone is 35 feet above the level of the railroad. Sixty feet below the level of the railroad, or 95 feet below the top of the Paris bed,

is the top of a series of fine-grained blue limestones referred to the Wilmore bed. That part of fine-grained limestone section which is above river level has a thickness of 16 feet. It contains *Modiolodon oviformis, Rhynchotrema inequivalve,* a variety of *Hebertella frankfortensis* with more numerous radiating plications than in the typical form, *Liospira vitruvia, Lophospira medialis,* and *Schizocrania filosa.* This *Schizocrania filosa* is oval in form, narrower posteriorly. The length of a well preserved specimen is 16 mm., its width is 15 mm., and the convexity of the dorsal valve is about 3 mm. Radiating striae numerous, about 12 in a width of 2 mm. Posterior adductor scars large, similar in form to those represented in figure 26, plate IV G, in the *Paleontology of New York,* vol. VIII, by Hall and Clarke from the Maysville formation at Cincinnati, Ohio. The anterior edge of the scars extends to 6.5 mm. from the beak. The anterior adductors are small, and are 8 mm. from the beak, and 4 mm. from each other.

Schizocrania filosa occurs in the Wilmore bed, and recurs in the Maysville formations, being known from the Fairmount, Bellevue, and Corryville beds.

Crania granulosa — cumberlandensis, var. nov.

(Plate V, fig. 8.)

A mile and a quarter southwest of Cumberland City, Tennessee, along the railroad, about half a mile south of the crossing of the Erin pike, a species of *Crania* occurs associated with *Dinorthis deflecta, Orthis tricenaria, Dalmanella subaequata, Strophomena incurvata, Rafinesquina minnesotensis,* and other fossils belonging to the Stones River Group. In Kentucky, equivalent strata occur at High Bridge, where a similar assemblage of fossils occurs in the Camp-nelson division of the High-bridge formation.

The specimens of *Crania* resemble in outline and size some of the specimens of *Crania scabiosa.* Some of the specimens attain a length of 10 mm. and a width of 12 mm. The outline, in general, is rounded, but the anterior margin usually is more or less straightened. The surface of the upper valve is of medium convexity, and the apex is rather blunt. Compared with *Crania setigera,* from about the same horizon in the northern states of the Mississippi valley, the granules are much more numerous. Compared with *Crania granulosa,* the shell is larger, less orbicular in outline,

and the granules are more or less elongated, as though the bases of setae. While the granules are scattered, there is a tendency toward arrangement in more or less radiating lines. *Crania granulosa* occurs in the northern states of the Mississippi valley in strata which are equivalent to the lower strata exposed at High Bridge, Kentucky, and at Wells creek, in Tennessee. The Wells creek specimens of *Crania* therefore may be much more closely related to *Crania granulosa* than their size and general outline would indicate.

Rafinesquina winchesterensis, sp. nov.

(Plate V, figs. 13 A,B,C.)

In the Greendale division of the Cynthiana formation, east of the Cincinnati geanticline, between Nicholas county and Madison county, in Kentucky, forms of *Rafinesquina* with relatively narrow widths are common.

In the form for which the term *Rafinesquina winchesterensis* has been selected, the posterior outline is quadrate, the sides either being parallel or converging slightly toward the hinge-line. Along the anterior margin, the outline is evenly rounded. In the typical forms, the length nearly equals, or even slightly exceeds the width, producing an elongate appearance. However, specimens in which the length equals only nine-tenths of the width are common. The earlier stages of the shell, including about two-thirds of its length when mature, are moderately convex, but the anterior third of the more mature shell is curved downward so as to give a decidedly convex appearance on anterior or lateral view. In one specimen, 31 mm. long and 32 mm. wide, the convexity is 10 mm. The hinge-area of the pedicel valve is large; 2 mm. in height at the beak, and parallel to the plane of the brachial valve. In the typical shells, the radiating striations alternate more or less in size, especially from the umbo to one-third the length of the shell from the beak. The muscular area of the pedicel valve is indistinctly defined anteriorly. The muscular area of the brachial valve presents the same features as most forms of *Rafinesquina* from the overlying Cincinnatian rocks. In specimens 31 mm. long, the thickness of the shell through the valves is 6 to 7 mm.

Forms possessing these characteristics are found between Pleasant Valley and Millersburg, between Colby and Winchester, at

Greendale north of Lexington, and between Million and Valley View.

The narrower, more typical forms of *Rafinesquina winchesterensis* are accompanied by others in which the width is somewhat greater, the posterior outline, however, remaining quadrate (plate v, figs. 14, 15 A,B). In these specimens the length usually equals nine-tenths of the width or less. These specimens usually have a less convex appearance, especially anteriorly. In a specimen 35 mm. long and 39 mm. wide, the convexity was 7 mm., and the thickness of the shell through the valves 4.5 mm. In these specimens the radiating striae of the pedicel valve are distinctly finer, especially along the posterior half of the shell, although becoming larger and alternating in size near and anterior to the middle. The striae of the brachial valve also are finer. For these flatter, finely striated forms, the term *filistriata* has been selected. As a matter of fact, some of the narrower, more convex specimens, resembling typical *Rafinesquina winchesterensis* in form, have numerous fine striae, but intermediate forms are to be expected in any attempt to differentiate the *Rafinesquinae*.

Rafinesquina fracta, compared with *Rafinesquina winchesterensis,* is a larger, flatter, and much thinner shell, although possessing a similar outline.

Specimens of *Rafinesquina* from the Eden formation, between Rogers Gap and Sadieville, agree with the variety *filistriata* in outline, but are thinner, and there is a distinct difference in the size of the striae, one to three finer striae being intercalated between the much more prominent primary ones. A similar alternation is faintly indicated on the brachial valve. The median plication may be slightly more distinct.

Rafinesquina declivis, James.

(Plate II, fig. 4; Plate V, figs. 12 A,B,C,D.)

The following description of *Rafinesquina declivis*, under the generic term *Strophomena*, was published by U. P. James in the *Cincinnati Quarterly Journal of Science*, vol. 1, p. 240, in 1874:

This shell is remarkable for the manner in which it is arched or bent over. Cardinal line of the ventral valve straight; area narrow; beak slightly projecting; cardinal line pointed at the extremities, extending, apparently, beyond the width of the shell below (owing to the sudden depression or curve of the lateral margins, directly forward of the points of the cardinal line, it has

this feature); lateral and front margins bent over at nearly right angles with the plane of the exterior of the valve. Shell slightly convex from the beak to the extremities of the cardinal line, and about two-thirds of the distance from the beak to the front, giving to the umbonal convex surface a subtriangular form. More than half the area of the shell is bent suddenly over. Surface covered by rounded radiating striae, a central and strong one more prominent than the others; about every fourth or fifth stria larger than the ones between; crossed by fine concentric lines. Striae increased by interstitial addition. Dorsal valve not observed.

Width, measuring along the cardinal line, seven-eighths of an inch; length about the same.

Position and locality—Cincinnati Group, near Boyd's station, on the Kentucky Central Railroad, about 30 miles south of Cincinnati.

Collected by U. P. James.

In the James collection, preserved in the Walker Museum at Chicago University, a series of specimens, numbered 2392, is labelled as forming the types of *Rafinesquina declivis,* James. Of these, the specimen here represented on plate V by figures 12 A, B. is regarded as the one originally described. It is characterized by the sudden downward flexure of the lateral margins of the shell resulting in a subtriangular form. It is this downward flexure which suggested the term *declivis.* The choice of this term is unfortunate since the strong downward curvature of the sides of the shell and the triangular form of the specimen here regarded as the one first described are due to the lateral compression and contortion of the containing rock, a very argillaceous, fine-grained limestone. All of the specimens belonging to the so-called series of types evidently were obtained from the same locality, the railroad cut a quarter of a mile north of the station, where the massive argillaceous limestone rises to a height of 25 feet above the railroad. This limestone lies directly below the base of the Eden formation. *Dalmanella multisecta* and a species of *Leptaena* occur within 11 feet of the base of the Eden. All of the specimens of *Rafinesquina declivis* in the series of types are characterized by the prominence of the median striation, and by the distinctness of every fourth, fifth or sixth one of the other radiating striae. However, several of the specimens have the sides and anterior portion only moderately deflected, and the specimen represented by figure 12 D, and another specimen not figured, do not even have the triangular form. In fact, figure 12 D probably represents the normal, not distorted, form of *Rafinesquina declivis,* although some of the specimens evidently were a little longer compared with the

width at the hinge-line. In addition to *Rafinesquina declivis,* the rock at Boyd's station contains *Ceratopsis intermedia,* Ulrich.

Leptaena tenuistriata, Sowerby.

The following description of *Leptaena tenuistriata* was published by Sowerby in Murchison's *Silurian System,* vol. 2, p. 636, and illustrated by figure 2a on plate 22, in 1839:

Semicylindrical, closely striated; top of the upper (pedicel) valve with 12 or more concentric rugae, convex; sides expanded.

A shell much resembling *L. depressa,* and about the same size, but ornamented with much closer striae and of a thinner substance.

Locality—Marloes Bay; Narbeth, Pembrokeshire; also at Gaerfawr in the Caradoc Sandstone of Montgomeryshire.

In the accompanying figure, 14 radiating striae are figured as occupying a width of 4 mm. The shell, viewed from above, is rather quadrate in appearance, the concentric wrinkles approaching the hinge-line nearly at right angles, and there being no conspicuous extension of the shell along the hinge-line. The main body of the pedicel valve is comparatively flat, the geniculate border bending abruptly downward. The concentric wrinkles are well defined.

In *Leptaena richmondensis* (this Bulletin, vol. xiv, plate iv, figs. 10 A,B), from the Richmond of Ohio, Indiana, and Kentucky, identified by Hall as *Leptaena tenuistriata,* the number of radiating striae often is only 9 in a width of 4 mm., the shell is shorter, and is conspicuously elongated along the hinge-line, the width frequently equalling twice the length. Moreover, the downward flexure of the geniculate border is less abrupt. The radiating striae are broad, separated by sharp, narrow grooves, and resemble pieces of cord in close juxtaposition.

In the Saltillo bed, at Clifton, Tennessee, a single small valve of a *Leptaena* was found (plate v, figs. 9 A,B), which resembles *Leptaena tenuistriata* in having 14 radiating striations in a width of 4 mm. These striae are rather sharp, and are separated by grooves equal in width to the striae. The concentric wrinkles are only moderately conspicuous. The body of the pedicel valve is comparatively flat, and the flexure at the comparatively short geniculate border is fairly abrupt. The shell is relatively shorter and broader than in the figure of the type specimen. Its length is about 11.5 mm., and its width, 18mm. While not identical with *Leptaena tenuistriata,* from the Caradoc of England, it probably

is more closely related to this species than is *Leptaena richmondensis,* which frequently is identified with the Caradoc species.

The Saltillo limestone is identical with the Hermitage limestone of the area covered by the Columbia folio, in Tennessee, and with the Logana of Kentucky.

The *Leptaena* from the Saltillo limestone is interesting chiefly because it indicates one of the earliest appearances of this genus in strata whose equivalent can be recognized in Kentucky. *Leptaena charlottae*, of Minnesota, may be an earlier form.

The succession of forms, in descending order, is as follows:

Leptaena richmondensis............Waynesville to Whitewater.
Leptaena richmondensis-precursor....Arnheim.
Leptaena gibbosa, James...........Economy.
Leptaena invenusta................Fulton or Lower Economy.
Leptaena tenuistriata, var..........Saltillo (Logana).

Plectorthis equivalvis, Hall.

(Plate II, figs. 13 A,B; Plate VI, figs. 17 A,B, 2,3.)

Plectorthis equivalvis was described by Hall from the Cincinnatian series at Cincinnati, Ohio, and a specimen from the Trenton at Middleville, New York, was doubtfully referred to the same species. The type specimen, from which figures 6 a to c, on plate 32, of the *New York Paleontology* was prepared, is not listed among the types preserved in the American Museum of Natural History in New York City, but a specimen bearing one of the green tags used by Hall to indicate his types occurs among a group, numbered 4490 and labelled *Plectorthis fissicosta,* and appears to have been the specimen used in the original description of *Plectorthis equivalvis.*

The length of this specimen is 15 mm., the width across the middle is 16 mm., the length of the hinge-line is 13 mm., and the thickness or depth of the shell is 8.3 mm. The contraction in front of the hinge-line is considerably less than is indicated in the drawings accompanying the original description, but similar errors occur in other figures on the same plate. The foramen is not exposed. The number of primary plications is about 20, increasing soon to 23, and about 6 millimeters from the anterior margin of the shell these primary plications are supplemented on each side by a secondary plication, thus forming fascicles of plications, consisting in each case of three plications, the primary plication being more conspicuous than the other two. The surface of the shell

is not clean. A certain quantity of foreign matter attached to the shell gave rise, in the original description, to the statement that the strong radiating plications are marked as if by the bases of short spines, or of squamose projections of the shell, which, in perfect specimens, indicate a character much like *Atrypa aspera.* This was a most unfortunate comparison, and readily accounts for the failure readily to identify this shell, once it had become separated from its original label. No other shell occurs in the Hall collection which even approximately resembles the outline of his *Plectorthis equivalvis.*

Plectorthis equivalvis belongs to one extreme of a group of shells which is very abundant in the Fairmount bed at Cincinnati, and vicinity. Usually the width is distinctly greater than the length, in the ratio of 10 to 8 or 7 (plate VI, figs. 3, 2). The tendency toward a trifid arrangement of plications is marked, but frequently only one of the secondary plications is present between two primary plications, and the term bifid, used in Hall's original description, becomes appropriate. Toward the anterior margin of the shell, the secondary plications are less conspicuously depressed below the level of the primary ones than in *Plectorthis fissicosta,* and this is their chief difference.

In a large suite of specimens from the Fairmount at Cincinnati, Ohio, considerable variation in the relative width of the shell may be noticed. Narrow individuals occur, but there appears to be no evidence that these occur regularly enough to be considered a variety. Apparently the narrow form selected as the type of *Plectorthis equivalvis* by Hall is representative only of individual variation, not of group variation. It is merely an individual specimen which has not grown to its full size laterally. Specimens of this type are never found in numbers at some one locality or horizon, but singly and widely separated. It is only when specimens from widely different localities and from different horizons are selected and brought together that the impression can be produced that there is a variety in which the shell is narrow. With the exception of very few specimens, the species proper consists of broad, not of narrow shells, and to these broad shells the name *Plectorthis equivalvis* should be applied even if the original type specimen was a narrow form.

It is needless at this late date to state that *Plectorthis equivalvis* is not present in any part of the Trenton of New York or elsewhere.

Plectorthis fissicosta, Hall.

(Plate VI, fig. 4.)

(Plectorthis fissicosta, type, this Bulletin, vol. XIV, pl. IV, fig. 5 A,B.)

The type of *Plectorthis fissicosta,* Hall, preserved in the American Museum of Natural History, and numbered 4490, agrees very well with the original description and with the general appearance of the accompanying figures. The length of this type specimen is 16.5 mm., the width is 21 mm., and the thickness probably was about 8.5 mm., but the latter can not be determined accurately since the specimen is crushed. There are 20 primary plications, of which 11 show the so-called fission of the plications very well, and 2 only poorly. The postero-lateral plications appear narrower and remain simple. The secondary plications are added about 9 mm. from the beak. Together with the primary plications they form groups or fascicles, each consisting of three plications among which the primary plications are much more elevated and more conspicuous. In the case of two fascicles, in case of this type, there are 4 plications, instead of 3, present.

Specimens of this type are rare in the upper part of the Fairmount bed at Cincinnati, Ohio, and occur as far west as Vevay, Indiana.

Plectorthis triplicatella, Meek, is founded upon a shell possessing the same characteristics, and this name should be dropped for the prior one, *Plectorthis fissicosta,* Hall.

Plectorthis fissicosta is a variety or direct descendant of the normal broad-shelled forms of *Plectorthis equivalvis,* of which the narrow specimen used as a type is only an individual variation. *Plectorthis fissicosta* is characterized by the great prominence of the primary plications, causing them to appear widely separated, especially along the middle parts of the shell. The secondary plications are intercalated at a considerable distance from the beak, thus adding to the appearance of the primary plications being separated by deep grooves. These features are possessed, although in a less accentuated degree, also by the specimen represented by figures 9 f, g, on plate 32, *New York Paleontology,* vol. 1, and there included as one of the forms of *Plectorthis plicatella.* This specimen, preserved in the American Museum of Natural History and numbered 695-2, is not well represented by the published figure. The secondary plications are not added until within slightly less

than a third of the distance from the anterior edge. Together with the primary plications, they form fascicles each consisting of three plications. The primary plications are not as prominent as in typical *Plectorthis fissicosta.*

Plectorthis plicatella, Hall.

(Plate VI, figs. 5 A,B.)

The types of *Plectorthis plicatella,* numbered 695-2, and preserved in the American Museum of Natural History in New York City, were obtained from the Fairmount at Cincinnati, Ohio. In this species, the young specimens usually have simple primary plications only, and specimens of this character may occasionally attain a width of 20 to 23 mm. Usually, however, large specimens show at least a trace of secondary plications at a distance of about 9 to 10 mm. from the beak, although these may be still comparatively obscure 13 mm. from the beak.

If this interpretation of the species be correct, *Plectorthis equivalvis* and *Plectorthis fissicosta* differ from *Plectorthis plicatella* chiefly in the distance from the beak at which the secondary plications make their appearance and in the relative prominence of the primary plications compared with the secondary ones.

The group, *Plectorthis plicatella, Pl. equivalvis, Pl. fissicosta,* characterizes the typical Fairmount fauna of Ohio, Indiana, and the immediately adjacent part of Kentucky. The southern Fairmount fauna, characterized by *Strophomena maysvillensis* and *Orthorhynchula linneyi,* may be termed the *Maury fauna,* since it is well represented in the so-called Leipers formation of Maury county, in Tennessee. This southern fauna extends northward across Cumberland river, and central Kentucky, toward the northern part of the latter state, and northeastward into the Alleghanies.

Plectorthis plicatella-trentonensis, from the Trenton of Minnesota (*Minnesota Paleontology,* vol. III, plate 33, fig. 5 to 7), and Wisconsin, is more constant in the absence of secondary plications, even in specimens attaining a length of 14 mm. It appears to be the stock from which the Fairmount species of the Cincinnatian areas were derived.

Plectorthis dichotoma, Hall.

The figures accompanying the original description suggest that the type of Plectorthis dichotoma was characterized by about 20

primary plications alternating with an equal number of secondary plications, except possibly at the postero-lateral angles of the shell. The secondary plications are distinctly less conspicuous and are added about half way from the beak of the anterior margin. The grooves between the primary and secondary plications are relatively wide, and are distinctly marked by concentric striations.

Specimens possessing these features may be selected from among the numerous individuals belonging to the broad form of *Plectorthis equivalvis* found in the upper Fairmount, west of Dillsboro station, in Indiana (plate V, fig. 16 A, B, C, D). In these specimens both the brachial and the pedicel valve appear less convex than in the broad form of *Platystrophia equivalvis* which abounds at Cincinnati, but it must be remembered that Hall compared his *Plectorthis dichotoma* not with this broad form but with the narrow individual used by him as a type. Compared with the type of *Plectorthis fissicosta*, the plications appear more numerous, and the entire shell less robust. Similar specimens occur at Cincinnati.

In the original description of *Plectorthis dichotoma,* however, the number of primary plications is given as 26 and these are stated to bifurcate uniformly half way from the beak to the anterior margin. The accompanying illustrations suggest that the number 26 may have been a misprint for 20, but as a matter of fact the number of primary plications frequently reaches 24 to 26 when there are no intercalated secondary plications near the postero-lateral angles. The emphasis on the regular dichotomous branching of the plications does not assist much in view of the fact that the increase in the number of plications is always by intercalation and not by dichotomous branching, and this intercalation is distinctly illustrated by the accompanying figures. The type of *Plectorthis dichotoma* has been lost.

Plectorthis jamesi, Hall.

(Plate II, figs. 9 A,B.)

The description of *Plectorthis jamesi* appears to have been based upon the series of specimens, numbered 4489, preserved in the American Museum of Natural History in New York City, and there labelled as the types. Among these, the largest specimen was figured by Hall and Whitfield, in the *Ohio Paleontology,* vol. 2, plate 1, figs. 21, 22, as the largest one of the type specimens. It has about 23 primary plications, increasing to about 50 at the

margin, chiefly by the intercalation of additional plications toward the anterior margin. The cardinal extremities are compressed vertically, and the lateral margin forms an angle of about 85 degrees with the hinge line. The sides of the ventral valve are somewhat flattened, and the middle is a little depressed toward the front. The area of this valve is only moderately inclined backward.

As a matter of fact, several of the specimens in this series of types undoubtedly belong to *Plectorthis neglecta.* These are the specimens which have given rise to the following parts of the original description:

Cardinal extremities usually truncate or *rounded*: Dorsal valve convex, becoming *gibbous*, with a shallow often scarcely defined *sinuosity* in the middle; middle of the ventral valve sometimes a little depressed towards the front.

Occasionally *Plectorthis neglecta* is distinctly sinuous along the anterior margin, due to a slight elevation along the median parts of the brachial valve, anteriorly, and to a corresponding flattening or depression of the pedicel valve. This inclusion of typical specimens of *Plectorthis neglecta* among the types of *Plectorthis jamesi* suggests either that the type of *Plectorthis dichotoma* was lost as long ago as 1861, or that the latter species was not identical with *Plectorthis neglecta.*

Associated with these specimens of the *Plectorthis neglecta* type, in this series of types described as *Plectorthis jamesi,* are a number of smaller specimens, which seem to have been regarded as the young of *Plectorthis jamesi,* and to have inspired the following parts of the original description:

Often the striae are *simple throughout,* and, when well preserved, are always marked by fine thread-like concentric striae, and towards the margin by a few lamellae of growth; this species in general form, *resembles Orthis plicatella;* but the area is much larger, and extends to the salient cardinal extremities; while in that species the extremities are usually rounded and the shell a little rounded below.

These smaller specimens belong in the Corryville bed, 100 feet above the *Plectorthis neglecta* horizon. Local collectors at Cincinnati have usually regarded these smaller specimens as the true types of *Plestorthis jamesi,* notwithstanding the fact that they are described in the second and third paragraphs of the original description, while the large specimen figured by Hall and Whitfield and the specimens of *Plectorthis neglecta,* already mentioned as occurring among the series of types, formed the basis of the first paragraph of the description. *Plectorthis neglecta* is found in the Mount Hope bed, but very

similar specimens occur in the lower Corryville east of Maineville, in Warren county, Ohio. It is possible that the large figured specimen also is a Corryville form. Its chief feature is the extended width of the shell along the hinge-line, the postero-lateral angles equalling about 85 degrees. In other respects the shell resembles some of the forms of *Plectorthis* found in the Fairmount bed (plate VI, fig. 2).

Plectorthis neglecta, James.

(Plate VI, figs. 1 A-E.)

Figure 21, plate V, of the *New York Paleontology,* vol. VIII, labelled *Plectorthis dichotoma,* is the interior of the Mount Hope species, *Plectorthis neglecta,* James.

The types of *Plectorthis neglecta,* numbered 2399, are preserved in the James collection, in Walker Museum at Chicago University. In this species the intercalation of secondary plications often begins within 3 or 4 mm. from the beak and additional plications may be added near the anterior margin. The secondary plications soon attain about the same height and width as the primary plications, so that the shell in general has a more closely and uniformly plicated appearance than any other species of Plectorthis found near Cincinnati. The grooves between the primary and secondary plications are narrow. Not infrequently the anterior half of the pedicel valve is slightly depressed or flattened.

Plectorthis neglecta makes its appearance in the Mount Hope bed, at Cincinnati, and extends at the same horizon southwestward to Vevay, Indiana, and southward to Mason, Kentucky. It distinctly precedes *Plectorthis plicatella* of the Fairmount, and must belong to a different line of descent.

Plectorthis dichotoma may be identical with *Plectorthis neglecta,* but in the absence of the type and in the presence of the figure accompanying the original illustration, this appears doubtful. It is unfortunate that among the numerous types in the Hall collection, the apparently aberrant types, *Plectorthis equivalvis* and *Plectorthis dichotoma,* should be missing or at least not definitely identified in the collections as types of these species. Under these conditions it might be preferable to abandon the doubtful term *Plectorthis dichotoma* for the definite one *Plectorthis neglecta.*

Hebertella sinuata, Hall.

(Plate II, fig. 5.)

Hebertella sinuata differs from *Hebertella occidentalis* chiefly in the absence of the slight median depression near the beak of

the ventral valve. Moreover, in the typical forms, the primary plications are distinctly coarser along the posterior half of the shell. Owing to bifurcation, these plications may appear less coarse near the anterior margin of the shell. The small specimen represented by figs. 2 a, g, i, n, on plate 32 B, of the *New York Paleontology*, vol. 1, is too small to show the characteristics of the species very well, and the originals of 2b and c can not be identified. On this account, the original of figures 2 d, h, k, and o have been selected for illustration in this paper.

Specimens of this type occur throughout the Richmond, and are especially common in the upper part of the Waynesville bed, but forms identical in character appear as low as the Bellevue, and in the upper Fairmount. The types are labelled as coming from Cincinnati, Ohio, but their original source and horizon is not definitely known.

In the original description it is stated that *Hebertella sinuata* occurs at Maysville, Kentucky, and at Cincinnati, Ohio, but that it is less frequently found at Oxford, Ohio, and at Madison, Indiana. This favors the Maysville formation as the source of the types.

Since the median depression near the beak of the brachial valve usually is too faint to be readily seen, and since it occurs both on shells having plications of medium size and on those having coarse plications, it appears doubtful whether the absence of this slight depression is sufficient to give name to a separate variety, especially in the Maysville representatives, although in the upper Waynesville and in the Liberty this feature becomes more constant. Moreover, it is difficult to differentiate between *Hebertella sinuata* and *Hebertella occidentalis* on the basis of the coarseness of the primary plications, except in the case of selected specimens. At the same locality all the intermediate stages are almost certain to be found. However, the discriminations proposed by Hall are of interest. These forms of *Hebertella* belong to what might be called a series of nascent species, not yet fully differentiated, corresponding to the numerous variations in the genera *Platystrophia, Plectorthis, Cyclocoelia,* and *Rafinesquina* during Maysville time.

Hebertella occidentalis, Hall.

(Plate II, figs. 1, 2.)

The chief characteristic of *Hebertella occidentalis* is the slight median depression near the beak of the brachial valve, which disap-

pears anteriorly. The radiating striae are of medium coarseness, compared with those selected as types of *Hebertella sinuata* and *Hebertella subjugata*. Specimens of this type are fairly common in the Richmond, ranging from the Arnheim to the Elkhorn, but they are especially common in the Liberty bed and in the upper part of the Waynesville. Forms apparently identical in character appear as low as the Corryville and upper Fairmount. It is not known from what horizon the types were obtained. They are labelled as coming from Cincinnati, Ohio, but this labelling frequently was used for specimens obtained from Richmond strata by the Cincinnati collectors.

In the original description, *Hebertella occidentalis* is cited from Maysville, Kentucky, Cincinnati and Oxford, Ohio, and Madison, Indiana. The Maysville and Cincinnati exposures probably were both in the Maysville formation. The Oxford and Madison specimens probably came from Richmond strata. This favors the source of the type specimens from the Maysville formation.

The specimen represented by figs. 2a, g, i, on plate 32 A, of the *New York Paleontology*, vol. 1, is too small to show the characteristic features of the species, as described, very well, and the originals of figs. 2b and d can not be identified. Therefore the specimen illustrated by figs. 2 c, k, and the one illustrated by figure o, on the same plate have been selected for illustration in the present paper.

Hebertella subjugata, Hall.

(Plate II, fig. 8.)

Hebertella subjugata differs from *Hebertella occidentalis* and *Hebertella sinuata* chiefly in the finer plications. There is no median depression near the beak of the brachial valve.

Specimens of this type are common in the lower and middle Eden, as exposed between Sadieville and Rogers Gap, and both east and west of Million, in Kentucky. At Cincinnati, similar specimens range from the Mount Hope bed upward through the Maysville, being more common in the lower beds. It occurs also in the Waynesville bed, and probably higher in the Richmond.

In the original description of this species, Cincinnati and Oxford, Ohio, Maysville, Kentucky, and Madison, Indiana, are mentioned. This favors the Maysville formation as the source of

the types, since the latter are labelled as coming from Cincinnati, Ohio.

Hebertella subjugata, in the Eden, appears to be a direct descendant of *Hebertella parksensis,* from the Greendale division of the Cynthiana formation. *Hebertella occidentalis* is regarded as a descendant of *Hebertella subjugata,* with *Hebertella sinuata* as another derivative.

Hebertella alveata — richmondensis.

(Plate V, fig. 10.)

In typical *Hebertella alveata* (this Bulletin, vol. XIV, plate IV, fig. 8A), the shell is considerably wider along the hinge-line than anteriorly, the postero-lateral angles being acute. In the variety *richmondensis,* plate V, fig. 10, the hinge-line is considerably shorter than the width of the shell across the middle, the postero-lateral angles are rounded, and the brachial valve is strongly convex, especially in the umbonal region. Both forms occur in the upper part of the Whitewater bed, at Richmond, Indiana, accompanied by intermediate forms (plate V, fig. 17). It is very doubtful whether the forms with a very short hinge-line should be distinguished even as a variety. *Hebertella alveata* makes its appearance already in the Liberty bed, although *Hebertella occidentalis,* characterized by the slight median depression at the beak of the brachial valve, disappearing anteriorly, is far more common there.

Platystrophia colbiensis, sp. nov.

(Plate IV, figs. 2 A, B.)

In the Cynthiana formation, between Colby and Winchester, in Kentucky, a small form of *Platystrophia* occurs in which the median fold is only moderately elevated, and not strongly compressed laterally, while the sinus is broad and shallow. Four plications occupy the fold, and three occur in the sinus. The number of lateral plications on each side of the fold varies usually from 8 to 9. The hinge-line may equal the width of the shell across the middle, but usually is a little shorter. The convexity of the shell is considerable, but rarely enough to be called gibbous. Owing to the small elevation of the fold, the brachial valve has a more evenly convex appearance than the small forms of *Platystrophia* occurring in the Mount Hope bed, and described by Meek under

the term *Platystrophia profundo-sulcata* (*Ohio Paleontology*, vol. 1, plate 10, fig. 2 a-d). The length of a typical specimen is 13.5 mm.; the width, 19 mm.; the thickness through the valves, 12 mm.; the elevation of the fold above the general convexity, slightly over one millimeter.

Specimens bearing these characteristics occur in the Greendale division of the Cynthiana bed at Pleasant Valley, and at the Lower Blue Lick Springs, in Nicholas county, and thence southwestward to Millersburg, Paris, and Lexington; along the railroad between Colby and Winchester; between Million tunnel and Valley View, all in Kentucky.

Similar specimens occur in the Paris bed at Lexington, Frankfort, and Drennan Springs, Kentucky. A small *Platystrophia* occurs 20 feet above the Ohio river, at Carnestown, Kentucky, associated with *Strophomena vicina,* in beds possibly equivalent to the Paris bed. Small specimens of *Platystrophia* occur also along the railroad between Rogers Gap and Sadieville, Kentucky, in strata containing *Clitambonites rogersensis.*

Platystrophia colbiensis-mutata, var. nov.

(Plate IV, figs. 3 A, B.)

By selection, it is possible to differentiate from among numerous specimens of *Platystrophia colbiensis* a much smaller number of individuals in which the number of plications on the fold is increased to six or more plications. Usually two initial plications are increased to four near the beak, and two additional plications are added on the sides of the fold within a third of the length of the shell from the beak, thus resulting in six plications. If any additional plications are present, these are added to the exterior side of the inner pair. Shells of this form are larger, broader, and less convex. The fission of the plications is confined to the fold, those on the sides remaining simple. In a typical specimen 15 mm. long, the width was 20 mm., the thickness through the valves 12 mm. The number of plications on the fold was 6, and 11 occurred on each side. In one specimen, 9 plications are found on the fold.

Specimens possessing these features are found at Pleasant Valley, and five miles west of Winchester, Kentucky.

In *Platystrophia fissicostata,* McCoy, the fission of the plications occurs on the sides of the shell as well as on the fold. *Platy-*

strophia reversata, Foerste, from the Brassfield or Clinton bed of Ohio is another mutation in which the fission of the plications is confined to the fold and sinus.

Platystrophia colbiensis — precursor, var. nov

(Plate IV, fig. 1.)

By selection from a large number of *Platystrophia colbiensis,* it is possible to differentiate a series of specimens characterized by a larger size, greater width, less convexity, in which the posterior part of the shell along the hinge-line frequently is slightly extended beyond the width of the shell across the middle. The width of an average sized specimen is 27 mm.; the length, 19 mm.; the convexity, 14 mm. Four plications occupy the fold, and 8 to 10 are found on the sides.

Specimens having these characteristics occur between Colby and Winchester, and also at various localities between Millersburg and Pleasant Valley, Kentucky. Specimens in which the hinge-line is slightly shorter than the width across the middle of the shell also occur.

Specimens of *Platystrophia ponderosa* make their appearance as early as the upper part of the Fairmount bed, associated with *Orthorhynchula linneyi,* along the eastern side of the Cincinnati geanticline, from Lincoln to Clark county. They may be traced at this horizon as far north as Maysville, Kentucky. Both forms with the hinge-line slightly longer than the width across the middle of the shell, and those with shorter hinge-lines occur one mile north of Paint Lick. These specimens differ from typical *Platystrophia ponderosa* chiefly in their smaller size. Specimens an inch and a quarter wide, resembling *Platystrophia ponderosa,* occur also just beneath the massive Garrard sandy limestones at the George Million locality, southeast of Million, Kentucky, and similar specimens are found near the base of the Upper Eden at Maysville. These lower specimens agree with *Platystrophia ponderosa* in possessing a low fold not laterally compressed, the number of plications being four on the fold, increasing occasionally to 5 or 6. If these forms actually belong to the *Platystrophia ponderosa* series, as they appear to do, the latter species may be of indigenous origin, and may have been derived from the larger varieties of the *Platystrophia colbiensis* type of shell.

Platystrophia profundosulcata, Meek.

(Plate VI, figs. 15 A-C.)

Platystrophia profundosulcata is a much smaller shell than *Platystrophia laticosta* and occurs usually at a lower horizon. It is very abundant at some localities in the lower Fairmount, especially near Cincinnati, Ohio, although numerous specimens occur also in the Mount Hope. In typical specimens, the sinus is much deeper and the fold stronger than in typical specimens of *Platystrophia laticosta* of the same size. Mature specimens average about 18 mm. in width. The length equals between seven and eight-tenths of the width, and the thickness varies between six and eight-tenths of the width. The hinge-line frequently is shorter than the width of the shell across the middle, but may equal the latter or even slightly exceed it. Specimens in which the lateral plications of the fold and sinus are almost or entirely obsolete are rare. Viewed from the side, the shell has a rather gibbous appearance. Usually 6 or 7 plications occur on each side of the fold, but specimens with 5 plications are not rare.

The specimens from the Mount Hope bed (plate IV, fig. 4) are closely similar to those from the lower Fairmount, but usually have the fold less strongly elevated and the sinus less profound. They are wider, and less convex. The width frequently reaches 20 mm. The number of plications usually is 6 or 7 but may vary from 5 to 10. At the Mount Hope horizon, this species usually occurs alone, not associated with any other form of *Platystrophia*. In the Fairmount, it may be associated with *Platystrophia laticosta*.

Platystrophia laticosta, Meek.

(Plate III, figs. 1 A, B.)

Platystrophia laticosta is characterized by the presence of 5 to 7 broad plications on each side of the fold. Both the fold and sinus are less compressed laterally than in *Platystrophia cypha*, and the lateral plications on the sides of the fold and sinus, though inconspicuous, are less commonly obsolete. The postero-lateral outline usually does not form angles more acute than 70 degrees. The shell is comparatively compressed antero-posteriorly. The typical specimens occur in the Fairmount bed, at Cincinnati, Ohio, and at corresponding horizons elsewhere, but similar forms occur also in the Bellevue bed at Madison, Indiana, Cincinnati, Ohio.

Maysville, Kentucky, and also in the overlying Corryville. Specimens having the same general aspect occur also in the Waynesville bed, but usually the latter (plate III, figs. 3, 4) have narrower and more numerous lateral plications.

Several specimens of *Platystrophia*, plate III, figs. 2 A, B, received from Prof. Ray S. Bassler, and labelled as coming from the Waynesville bed at Waynesville, Ohio, can not be distinguished from many of the specimens of *Platystrophia laticosta* from the upper Fairmount, Bellevue, and lower Corryville horizons at Cincinnati, Ohio.

The later forms of *Platystrophia laticosta* are distinguished by the comparative distinctness of the lateral plications of the fold and sinus, which, although less conspicuous than the primary plications, are more distinct than in *Platystrophia cypha*.

It has been suggested that *Platystrophia acutilirata* was derived from *Platystrophia laticosta*, but some forms of *Platystrophia cypha* also appear available as a source of *Platystrophia acutilirata*.

Platystrophia crassa, James.

(Plate IV, figs. 5 A, B.)

In the *Cincinnati Quarterly Journal of Science*, vol. 1, p. 20, in 1874, U. P. James proposed the specific name *crassa* for the species illustrated in the *Ohio Geological Survey, Paleontology*, part 2, vol. 1, p. 117, plate 10, fig. 3, under the name *Platystrophia dentata*.

The first specimen figured, illustrated by figs. 3 a-c, has a hinge-line slightly longer than the width of the shell across the middle. Only two plications occur on the fold, and one in the sinus. The fold is prominent and narrow, and the sinus is correspondingly deep. The second specimen illustrated, fig. 3 d, has a somewhat different expression owing to the fact that the hinge-line is distinctly shorter than the width of the shell across the middle. The fold and sinus are similar to those of the first figured specimen, but a small additional plication occurs both in the sinus and on the fold. Neither of the specimens exceeds three-quarters of an inch in width. Meek, however, included also specimens an inch in width, and he gave the horizon as 250 to 300 feet above low water mark at Cincinnati, Ohio. This is the horizon from which Meek lists also *Strophomena planoconvexa*, *Dalmanella*

bellula, Cyclocoelia ella, Plectorthis plicatella, and evidently is the Fairmount horizon.

James, in proposing the term *crassa,* includes specimens equalling an inch and a quarter in width, and gives the horizon as between 300 and 400 feet above low water in the Ohio river at Cincinnati. This would include the Corryville. The specimens from the Fairmount bed are here regarded as typical. It should be noted, however, that the specimens studied by Meek were sent to him by James and Shaffer of Cincinnati and evidently were selected specimens. There is no species in the Fairmount at Cincinnati which is characterized by the presence of only two plications on the fold and one on the sinus. By far the greater number of specimens have four plications on the fold and three in the sinus, but the two lateral plications on the fold are always less conspicuous and situated lower, on the sides of the fold. Frequently, these lateral plications are quite inconspicuous, are placed half way up the sides of the fold, and are matched by similar inconspicuous plications half way down the sides of the sinus. Specimens without any trace of the lateral plications (the typical forms of Meek) are very rare, and can be regarded as only aberrant forms of an otherwise abundant species. The hinge-line generally about equals the width of the shell across the middle, but may be slightly greater or less. The number of plications on each side of the fold usually is 5 or 6 but may equal 7. Specimens seven-eighths of an inch in width are not rare at the Fairmount horizon, but the average width is nearer three-quarters of an inch.

Platystrophia costata, Pander, is a much smaller species with a low fold and shallow sinus not strongly compressed laterally, and having an entirely different aspect viewed from the anterior side.

Platystrophia morrowensis, James.

(Plate VI, figs. 11 A,E; 12 A,B.)

In the James collection, in Walker Museum at Chicago University, there are several specimens labelled as the types of *Orthis morrowensis.* Only one of these was present at the time of original description of the species, and this is sufficiently characterized by its very short hinge-line, equalling about one-third of the greatest width of the shell. The general outline is oval, broader than long. The width is 9.7 mm.; the length, 7.7 mm.; and the thickness through the valves, 5 mm. The median fold is only

moderately elevated, and is marked by four plications, two of which bifurcate anteriorly, but this is only an individual characteristic. As a rule, shells of this species have only four simple plications on the fold. Three plications occur in the sinus. The type (plate VI, figs. 11 A,E) is also abnormal in presenting an exceptionally short hinge-line.

Most specimens of *Platystrophia morrowensis,* as here interpreted, differ from the type of the species in having a distinctly longer hinge-line, frequently equalling four-fifths of the width of the shell. To specimens of this character, Ulrich gave the catalogue name, *Platystrophia similis.* Ulrich's specimens were secured 15 feet below the top of the Corryville bed, at Cincinnati, Ohio.

The very low, broad fold, and short hinge-line suggest young specimens of *Platystrophia ponderosa,* a much larger species occurring in the Mount Auburn bed, 15 feet higher. In *Platystrophia ponderosa,* however, the two primary plications on the fold are distinctly more conspicuous than the secondary plications within 7 mm. of the beak, and the two secondary plications are added at a distinctly lower level, at a distance of 3 or 4 mm. from the beak, while at this distance, those of *Platystrophia morrowensis* are already distinctly differentiated and lie very nearly at the same level. Moreover, all of the plications of *Platystrophia morrowensis* are sharper and more distinct than any specimens of *Platystrophia ponderosa* of the same size.

Platystrophia cypha, James.

(Plate IV, fig. 10 A,B; Plate V, fig. 11.)

The type specimen possessed the following characteristics: Shell elongated along the hinge-line into spine-like projections, being over two-thirds wider here than across the center of the shell, as is indicated by the following measurements. Width along the hinge-line, one and a half inches; width half way below the hinge-line, less than an inch; length, three-quarters of an inch. Shell extremely gibbous, the convexity equalling the width of the body below the spine-like projections. Brachial valve with a remarkably elevated median fold whose flanks form an angle of about 80 degrees with the sides of the shell. Pedicel valve with a profound sinus. Sinus with one strong elevated plication in the center and an obscure elementary one on each side. Fold with two strong plications on the crest, and although no obscure rudimentary plica-

tions are mentioned as occurring on the flanks, these must have been there in order to match those described in case of the sinus. Ten to twelve plications occur on each side of the fold. The anterior face of the shell, along the line of junction of the fold and sinus, is nearly flat or moderately convex. Compared with *Platystrophia crassa*, the shell is larger, more gibbous, has a more profound and longer sinus, a longer hinge-line, and more numerous plications.

Among the series of specimens preserved in the James collection in the Walker Museum of Chicago University as types of *Platystrophia cypha*, and numbered 2326, only one (plate iv, figs. 10 A,B, and plate v, fig. 11) is prolonged conspicuously along the hinge-line; it possessed twelve plications on each side of the fold. The spine-like projection on one side of the shell extends to about three-quarters of an inch from the beak. The spine-like prolongation at the opposite end of the hinge-line has been broken off. The other specimens can not be regarded as types since in these the prolongation of the shell along the hinge-line does not exceed an eighth of an inch and the number of plications on each side of the fold is 7 or 8 instead of 10 to 12. Although all of these specimens can not be regarded as the original types, they evidently all belong to the same species, if my interpretation of the limits of this species is correct.

The normal form of the species, to one extreme of which the name *Platystrophia cypha* has been applied, is characterized by the deep sinus and prominent fold, with one prominent plication in the sinus and two on the crest of the fold. There is a strong tendency toward the disappearance of the lateral plications of the sinus and fold, which is shown by their comparatively inconspicuous size and their situation half way down the flanks of the fold and the sides of the sinus. Occasionally, one of these lateral plications is entirely obsolete both in case of the sinus and the fold. Less frequently, both lateral plications are absent on the fold and also on the sides of the sinus. The number of lateral plications on each side of the shell usually varies from 6 to 8, and increases to 10 and 12 as a rule only in case of shells which are conspicuously prolonged along the hinge-line.

Shells conspicuously prolonged along the hinge-line and with 10 to 12 plications on each side of the fold were selected by James as the type of his species, *Platystrophia cypha*.

Shells belonging to the opposite extremity of the series, with the postero-lateral angles almost rectangular, with only 5 or 6 lateral plications, and with the lateral plications on the fold and on the walls of the sinus almost or entirely obsolete, form the *Platystrophia unicostata* of Cumings. (Plate IV, fig. 6.)

Between these extremes belongs the larger series with only a moderate extension along the hinge-line, with 6 to 8 lateral plications on each side of the fold, and with the lateral plications of the fold and sinus more frequently present, though inconspicuous.

All the variants of *Platystrophia cypha* have been found in the upper part of the rich *Platystrophia ponderosa* beds at the Bellevue horizon, and in the overlying Corryville beds at Madison, Mount Sterling (plate IV, fig. 12 A,B), Vevay, and New Hope church in Ohio county, in Indiana. This may have been the horizon also at which James collected his type specimens in Warren county, Ohio.

Cumings has pointed out the probable derivation of *Platystrophia unicostata* from *Platystrophia laticosta* of the Fairmount bed. The later developments of *Platystrophia cypha* also are of interest.

If emphasis be laid on the prominence of the fold, the depth of the sinus, the tendency toward prolongation along the hinge-line, and the inconspicuous size and low position of the lateral plications of the fold rather than their absence, then the descendants of *Platystrophia cypha* can be recognized readily in the Arnheim. For instance, one mile south of Mount Washington, and a mile south of Smithville, on the road from Louisville to Bardstown; near Lebanon; three miles south of Maysville, Kentucky (plate iii, fig. 5). Also three miles northeast of Goshen in Clermont county, and at Oregonia in Warren county. At the locality one mile south of Mount Washington, Kentucky, specimens with spine-like prolongations along the hinge-line were found which agree with James's original description better than does the best of his series of type specimens.

A somewhat similar group of specimens occurs in the Waynesville bed. In this group, the lateral plications on the fold sometimes are inconspicuous and situated low on the flanks, but more frequently they are farther up the sides of the flanks and tend to be more conspicuous than in the case of shells from lower horizons. Shells of this type occur in the Waynesville at Madison, and Versailles, Indiana, at Oregonia, and Clarksville, Ohio, and at Con-

cord, Kentucky. They range as high as the upper or Blanchester division of the Waynesville bed at Moores Hill, Indiana (plate iv, fig. 13 A,B), and at Woodville, in Clermont county, Ohio.

Possibly *Platystrophia acutilirata* was derived from the *Platystrophia cypha* stock. In that case the process of evolution demands a reduction in the height of the fold and an increase of the size and elevation of the lateral plications of the fold; in other words, a reversal in part to former conditions. The tendency toward prolongation along the hinge-line and toward a larger number of lateral plications on each side of the fold than in *Platystrophia laticosta* remains. The possibility of the derivation of *Platystrophia acutilirata* in a more direct line from *Platystrophia laticosta* must be considered elsewhere.

The typical characteristics of *Platystrophia cypha* are the high median fold of the brachial valve, the deep sinus of the pedicel valve, with a tendency toward the disappearance of the two exterior plications from the group of four plications occupying the fold, and from the group of three plications occupying the sinus. While the shell is prolonged into a spine-like projection along the hinge in the type specimen, this is an extreme form of the species. In the Arnheim bed, half a mile south of Smithville, in Bullitt county, Kentucky, and at corresponding horizons elsewhere in Kentucky, west of the Cincinnati geanticline, a form of *Platystrophia* occurs (plate iv, figs. 7 A,B, and 14 A,B.) which may represent a line of development from *Platystrophia cypha* toward *Platystrophia acutilirata*. In these specimens the sides of the shell, on each side of the fold and sinus, on ventral view, appear compressed instead of inflated as in typical *Platystrophia cypha*. However, some of the specimens show a fairly conspicuous fold and sinus, and there is a tendency toward the disappearance of the exterior pair of plications of the fold and sinus (figs. 7 A,B), while in other specimens the elevation of the fold and the depth of the sinus are distinctly less, the exterior plications of the fold and sinus are more conspicuous, (figs. 14 A,B) and this type of shell may have led to *Platystrophia acutilirata*. There is a considerable variation in the number of lateral plications, but these tend to be numerous in the broader shells. For shells of this type the name *Platystrophia cypha-conradi* is proposed.

Platystrophia cypha-conradi appears to have been a precursor of the type of shell which is very prolonged along the hinge-line,

is of only moderate length, and which shows a tendency toward the disappearance of the exterior plications of the fold and sinus. Shells of this type(plate iv, figs. 11 A, B) occur in the Liberty bed at Versailles, Indiana, and for these the name *Platystrophia cypha-versaillesensis* is suggested. Similar specimens occur in the Blanchester division of the Waynesville bed along the road from Moores Hill to Holman, north of Hogan creek (plate iv, figs. 13 A.B).

Platystrophia acuminata, James, from the Mount Auburn or lower Arnheim at Cincinnati, Ohio, judging from its relatively great width and acute postero-lateral angles, belongs to the *Platystrophia cypha* group of shells, and may be merely a young specimen of one of those forms in which the lateral plications on the fold and in the sinus are better developed. The type (plate vi, figs. 13 A,B) numbered 1562, is preserved in the James collection in the Walker Museum, at Chicago University.

Platystrophia clarksvillensis, sp. nov.

(Plate III, figs. 4,3.)

In the Clarksville division of the Waynesville bed there is a form of *Platystrophia* which bears some resemblance to *Platystrophia laticosta*. (Fig. 4.) It differs chiefly in having narrower, more numerous plications, the number of lateral plications being 7 to 9; the four plications occupying the fold are more nearly of the same size, resulting in a relatively broader and less angular fold and sinus. These specimens closely resemble *Platystrophia acutilirata* but differ in having a less obese convexity when seen from the anterior side. The specimens possibly may be in the line of development from *Platystrophia laticosta* toward *Platystrophia acutilirata*. They are especially common in the Clarksville division of the Waynesville bed, but they begin in the Fort Ancient division, are found in the Blanchester division, and continue into the Liberty bed. Typical forms of *Platystrophia acutilirata* occur in the Whitewater bed.

Platystrophia acutilirata, Conrad.

(Plate III, figs. 6, 7, 8 A, B.)

Conrad described *Platystrophia acutilirata* as coming from the Silurian shale at the Falls of the Ohio river, Kentucky. Since his

species unquestionably is from some horizon in the Richmond group, and since no part of the Richmond is exposed in the immediate vicinity of Louisville, it is evident that his type must have been obtained from some other locality.

It is customary to identify as *Platystrophia acutilirata* the Whitewater form which is so abundantly exposed at Richmond, Indiana, and at corresponding horizons in Ohio and Indiana. This view is favored by the ventricose appearance of the body of the shell, mentioned in the original description and indicated in the accompanying figure; also by the acute hinge extremity and by the relatively considerable number of lateral plications. In the original description 32 lateral plications are mentioned which would result in 16 plications on each side of the fold. In the accompanying figure, 12 plications are represented on one side and 14 on the other side of the fold.

As a matter of fact, however, the Whitewater bed does not appear to be exposed nearer than Versailles, Indiana, and the Liberty representatives of this type of *Platystrophia* rarely have more than 11 lateral plications on each side of the fold, although such specimens do occur occasionally, but even then the number does not equal 14 or 16. The Liberty bed, however, is abundantly exposed at numerous localities within 30 miles of Louisville, and is richly fossiliferous.

Specimens with numerous lateral plications occur also at numerous localities in the Arnheim bed west of the Cincinnati geanticline between the Ohio river and Lebanon, Kentucky. One of these localities, south of Salt river on the road from Louisville to Bardstown, was along one of the chief lines of travel at the time Conrad wrote his description. The specimens of *Platystrophia* found here (plate iv, figs. 7 A,B, 14 A,B) are characterized by the prominence of the fold, the depth of the sinus, the sharpness of the plications, the acute lateral extremities, and by the antero-lateral compression of these extremities which gives them a wing-like rather than spine-like appearance. The number of lateral plications on each side of the fold frequently is 11, and sometimes equals 14. Similar shells, found in the Arnheim along the same line of travel, one mile south of Mount Washington, are more ventricose, and occasionally have more spine-like projections of the shell along the hinge-line, and numerous lateral plications, but only in case of selected specimens.

In general outline, in the ventricose appearance of the body of the shell, and in the number of plications, however, Conrad's figure resembles the common Whitewater form from the vicinity of Richmond, Indiana, and from corresponding horizons in Ohio and elsewhere in Indiana, rather than the Liberty or Arnheim forms seen within a reasonable radius of Louisville, Kentucky. His type specimen evidently was mislabelled as far as the locality was concerned. Conrad described other species from Richmond, Indiana. This identification of *Platystrophia acutilirata* with the Whitewater form is in common use, and nothing can be gained by seeking some Kentucky source for the origin of Conrad's type, especially in view of the absence of the type specimen itself.

As in the case of *Platystrophia cypha,* there is every variation between specimens in which the length of the hinge-line does not exceed the width of the shell across the middle, or even is a little less, and those in which the shell is prolonged into spine-like projections along the hinge-line.

The first mentioned extreme forms the variety *inflata* of James. Specimens of this type (plate iv, fig. 8 A,B) are strongly gibbous. The hinge-line about equals the width of the shell, and the latter is not more than one-fifth greater than the length in specimens which are considered most typical of this variety. One of the type specimens preserved in the James collection in the Walker Museum of Chicago University, belonging to a series labelled *Platystrophia inflata* and numbered 1561, has the following dimensions: length, 17.5 mm.; width across the middle of the shell, 23 mm.; length of the hinge-line, 23.5 mm.; gibbosity of the shell, 21 mm. The characteristic low, broad, rounded fold and shallow sinus of *Platystrophia acutilirata* are present.

The other extreme (plate iii, figs. 8 A,B), called *Platystrophia prolongata* by James, consists of shells distinctly prolonged along the hinge-line into spine-like projections. Frequently these projections are merely distinctly acute, with a slightly concave outline on the lateral side of the shell, and scarcely can be called spine-like. Specimens of the latter type form the typical *Platystrophia acutilirata* of Conrad, as here identified and as figured by Meek in the *Ohio Paleontology,* vol. 1, plate x, fig. 5a.

Platystrophia acutilirata-senex, the gerontic characteristics of which are so admirably described by Cumings, includes two forms. The one first figured (*Indiana Geol. Survey,* 32nd Report, 1908,

plate 35, fig. 4) corresponds essentially to typical *Platystrophia acutilirata* of Conrad and Meek. Figures 4 a-c on the same plate correspond to the variety *inflata* of James.

Platystrophia annieana, James, consists of shells evidently belonging to the typical *Platystrophia acutilirata* group, but differing in having the lateral margins convex rather than concave. The tendency toward a spine-like prolongation of the shell along the hinge-line, in other words, is missing. Viewed directly from in front, these shells appear more evenly convex, and less ventricose centrally. The number of lateral plications varies from 12 to 16 on each side of the fold. Specimens of this type occur at various horizons, but only as selected specimens, and not in sufficient numbers to suggest more than individual characteristics. James's types (No. 84, James Collection, Walker Museum, Chicago University) were secured in the upper part of the Waynesville bed, at Blanchester, Ohio. (Plate vi, figs. 14 A-C.)

Typical *Platystrophia acutilirata* is characterized by the low, broad, rounded fold, with four plications of approximately equal size, a strongly ventricose shell, and rather numerous lateral plications on each side of the fold. Shells of this type, with all the variations, from *Platystrophia inflata* to *Platystrophia prolongata*, occur everywhere in the Whitewater bed, in Indiana and Ohio. The specimens from the upper part of the Whitewater bed at Richmond, Indiana, and Dayton, Ohio, are especially typical.

Specimens belonging to the *Platystrophia inflata* group, but with the width distinctly greater than the length, and the number of lateral plications often as low as 7 to 9 on each side of the fold, are common in the representatives of the Whitewater bed in Ripley, Jennings, and Decatur counties, Indiana.

Forms similar to *Platystrophia inflata* occur in the Liberty bed, on the west side of the Cincinnati geanticline, as far south as Raywick, Kentucky. They are associated at Cane Springs, Bardstown, and elsewhere, with forms having the lateral outline of typical *acutilirata,* but all of these Liberty forms are distinctly less ventricose than those from the Whitewater bed near Richmond, and there is a tendency toward fewer lateral plications on each side of the fold. The fold frequently is more elevated, especially along the middle.

Two distinct types of shells occur in the Waynesville bed. In one of these, the fold is prominent, and the lateral plications on the

fold are distinctly less conspicuous and placed lower. Shells of this type appear to grade into *Platystrophia cypha*. Both shells with acute postero-lateral outlines, as in case of *Platystrophia acutilirata*, and shells with rectangular postero-lateral outlines are present, for instance at Madison, Versailles, and Bull creek, Indiana.

In the other type of shell found in the Waynesville bed (plate iii, figs. 3, 4), the fold is lower, the plications on the fold are more nearly of equal size, the shell is broader than in *Platystrophia inflata*, but the postero-lateral outline is approximately rectangular or but moderately acute. Specimens of this type grade into a form with relatively few plications, and somewhat resembling *Platystrophia laticosta*. Specimens of this type occur at Concord, Kentucky; Fort Ancient, Oregonia, and Waynesville, Ohio; and at Versailles and Madison, Indiana. Some of the specimens at Concord, Kentucky, resemble *Platystrophia inflata* in outline.

With numerous specimens from all horizons and from widely separated localities in Ohio, Indiana, and Kentucky at hand, it has been found impossible to determine the exact line of derivation of *Platystrophia acutilirata*. Much remains to be done. Future work will require a study of *Platystrophia* by faunal associations, its range of variation within those associations, and the spread of these variations along with the general associated faunas, geographically as well as vertically. The collection of prodigious quantities of specimens from some large vertical section is a valuable factor in such a problem, but in itself is insufficient to solve the complicated problem involved. Owing to the enormous amount of material which could be readily collected, the line of development of the various forms of *Platystrophia* will remain an interesting problem for a long time. The admirable studies by Prof. E. R. Cumings are classic. The notes here presented are merely an attempt to call attention to some of the species and varieties present in the area of the Cincinnati geanticline in such a manner as to give a little more definiteness to some of the names commonly used or almost forgotten.

Clitambonites rogersensis, Foerste.

A comparison of *Clitambonites rogersensis* from the Rogers Gap division of the Economy bed, at Rogers Gap, Kentucky, with typical specimens of *Clitambonites diversus*, Shaler, has shown that the Kentuckian form is more distinct than at first supposed. The

interior of the shell of *Clitambonites diversus* is covered by coarse intertwining vascular markings, which in *Clitambonites rogersensis* are comparatively inconspicuous. The shell of *Clitambonites rogersensis* is broader and shorter. The pedicel valve, in consequence, appears less convex, and the beak appears less conspicuously elevated. The brachial valve is transversely elongate, while that of *Clitambonites diversus* is subquadrate in outline. The anterior outline of *Clitambonites rogersensis* not infrequently is slightly reentrant or concave, but this is not a constant feature.

Opisthoptera concordensis, sp. nov.

(Plate I, fig. 9.)

Along the creek east of Concord, Kentucky, the *Strophomena concordensis* zone is almost at the base of the actually exposed section, a short distance south of the railroad bridge. Five and a half feet lower, the lowest specimens of *Streptelasma vagans* were found, associated with a species of *Opisthoptera*. Five feet higher, *Streptelasma vagans* and *Columnaria alveolata* occur. Seven and a half feet above the *Strophomena concordensis* layer, the species of *Opisthoptera* occurs again, associated with the lowest specimens of *Dalmanella jugosa* found at this locality. A specimen of *Opisthoptera* collected from the higher horizon just mentioned possesses the following characteristics:

Greatest length of the left valve, from the beak to the ventral border, 75 mm. Greatest convexity of this valve, 15 mm. Byssal opening well defined. About 20 primary plications reach the beak. Along the more elevated part of the valve, within 40 mm. from the beak, these primary plications are dichotomously divided into two. Anteriorly and posteriorly this division takes place nearer the beak. Along the ventral third of the main body of the shell, an additional plication occupies the depression between the pairs of more prominent plications resulting from this dichtomous division. Posteriorly, the intercalated plications have about the same prominence as the pairs resulting from the division; in consequence, the shell appears here more closely and evenly plicated. Anteriorly, the posterior division of the primary plication appears more prominent.

This species appears closely related to *Opisthoptera alternata,* Ulrich. It is distinguished by the paired appearance of the dichotomously divided primary plications over the larger part of the body of the shell.

Pterinea (Caritodens) demissa, Conrad.

(Plate I, fig. 10.)

Pterinea demissa, Conrad, as identified from the Cincinnatian strata of Ohio, Indiana, and Kentucky, differs from *Pterinea laevis,* the type of the genus, in the absence of a well defined, longitudinally striated ligamental area. Along the hinge line, a narrow linear portion is bent parallel to the general plane of the valves, and then inward along the margin, serving as an area of attachment of the valves but without any ligamental thickening or striation. No anterior cardinal teeth have been seen. The anterior muscular scar must be faint, since it has escaped detection so far. Agreeing with *Pterinea* are the greater convexity of the left valve, the low convexity of the right valve, becoming flat or slightly concave ventrally in mature shells, the well developed ear and wing, and the obliquity of the body. The posterior muscular scar is large, but not sharply impressed.

In the Whitewater bed, west of Camden, Ohio, the cast of both valves is marked along the line of junction between the body and the wing by a deep groove, 12 mm. in length in specimens 55 mm. high. These grooves indicate the presence of a single prominent linear posterior tooth in each valve. A similar specimen was found in the Hitz layer, at the top of the Saluda bed, at Madison, Indiana. Careful search among the numerous specimens of *Pterinea demissa* in the Arnheim and Waynesville beds has failed to reveal similar posterior teeth on well exposed interiors, nor have any been found in specimens from the Maysville formation. Possibly the Whitewater forms here described belong to a different species.

Pterinea demissa appears to be a distinctly more primitive type than *Pterinea laevis.* This is true especially of the Maysville and lower Richmond forms in which the posterior lateral teeth appear to be absent. These earlier forms are here chosen as the type of the more primitive group for which the term *Caritodens* is proposed.

A valve from the Arnheim bed at Clifton, Tennessee (Plate I, fig. 10) is identified with *Pterinea demissa.*

Conocardium richmondensis, sp. nov.

(Plate II, figs. 21 A,B.)

Shell sub-trigonal; hinge-line straight; beaks apparently

anchylosed and forming a transverse ridge which is extended into the umbonal ridge separating the anterior truncated face from the posterior part of the shell. This umbonal ridge is formed by the most prominent plication on the shell. It is angular, the anterior face of the shell being deflected almost at right angles to the posterior body. The anterior face extends as an obtusely angular cone about one millimeter beyond the umbonal plane, and then is produced as a laterally flattened acute extension along the hinge-line for an additional distance of at least two millimeters, the extreme tip not being preserved in the specimen at hand. Viewed from in front, this extension appears like a vertical lamella, extending downward into the sharp angle formed by the junction of the anterior margin of the valves. Anterior to the acutely angular umbonal ridge is a low, broad plication, about one millimeter from the umbonal ridge at the ventral margin. Anteriorly, this plication is distinctly limited by a strong groove extending as far as the beak; posteriorly this plication is limited by another groove, distinct only along the ventral half of the shell. Four or five practically obsolete plications intervene between the prominent one just described and the anterior extension of the shell. Posterior to the umbonal ridge, the umbonal region is marked by two distinct plications, the first of which is about one millimeter from the umbonal ridge, and the second is about a third of a millimeter from the second. Deep grooves intervene between the plications of this umbonal region, the anterior groove being broad and conspicuous. Posterior to the second plication from the umbonal ridge, the shell is constricted distinctly, and this posterior region is marked by distinct but narrow plications, of which twelve or thirteen reach the hinge-line in the specimen at hand. Several additional striae are intercalated anteriorly, and the posterior border is imperfectly preserved. Conspicuous striae, parallel to the ventral margin of the shell, cross the posterior region of the shell, and produce a net-work with approximately quadrate meshes. In the umbonal region these striae appear to be almost obsolete. The anterior face of the shell is marked by a net-work of extremely fine striae, part parallel to the plications already described, and part parallel to the ventral margin of this part of the shell. These striae are visible only under a strong light carefully directed, when examined by a strong lens. The umbonal ridge makes an angle of about 115° with the hinge-line. The distance from the beaks to the ventral margin of the shell at

the umbonal ridge is 5.5 mm. The distance of the beak from the posterior end of the shell, as far as preserved, is 3.5 mm. The distance from this posterior end of the shell to the ventral margin at the umbonal ridge is about 6.3 mm. The ventral margin makes an angle of about 35° with the hinge-line.

Since only a single specimen of this species is known, it may be necessary to modify this description eventually, but the specimen is sufficiently distinct from all others hitherto described to make its chief characteristics apparent.

Conocardium richmondensis was found 15 feet below the Clinton or Brassfield limestone, on Elkhorn creek, three miles south of Richmond, Indiana, associated with *Beatricea undulata, Streptelasma vagans, Columnaria alveolata, Columnaria vacua, Hebertella sinuata, Platystrophia acutilirata, Platystrophia moritura, Schizolopha tropidophora, Helicotoma marginata,* and *Ischyrodonta ovalis.* The conspicuous *Ischyrodonta* layer occurs immediately above.

Conocardium immaturum, Billings, from the Black River limestone at Paquette Rapids, on the Ottawa river, has a much broader umbonal region marked by numerous radiating striae.

Clidophorus, sp.

(Plate I, figs. 8 A, B.)

A species of *Clidophorus* occurs in the Saltillo bed, at Clifton, Tennessee, which closely resembles *Clidophorus neglectus,* Hall, from the Maquoketa shales of the upper Mississippi basin, but the umbonal ridge is less angular, the posterior outline is more rounded, and the clavicle, instead of sloping backward, slopes forward, leaving a shorter anterior muscle scar. It probably is a new species, but difficult to differentiate from some of those already defined.

Suecoceras inaequabile, Miller.

(Plate I, figs. 1, 2.)

Endoceras inaequabile was described by S. A. Miller from the Richmond group at Bristol, Illinois. It consists of the lower end of the siphuncle, showing the impressions of the septal necks as far as the tip, indicating that the nepionic bulb had been completely incorporated into the phragmocone. These impressions are inclined away from the apical end and toward the straight side of the nepionic part of the siphuncle.

A similar specimen was found at Clarksville, Ohio, in the

Orthoceras fosteri bed, at the base of the Middle or Clarksville division of the Waynesville bed. The specimen had been crushed laterally toward the apical end. The distance between the septal impressions is 7 or 8 mm. At and beyond a distance of 75 mm. from the apical end, these impressions are distinct. Nearer the apical end, these impressions are represented chiefly by equally distant transverse, oblique wrinkles.

A much smaller, but otherwise similar specimen was found in the Richmond group at Madison, Indiana, presumably in the Waynesville member.

The similarity to *Succoceras* appears confined to the exterior appearance of the nepionic bulb. No structure can be detected within this bulb. The upper end of the specimen from Clarksville is covered on one side by a thin encrusting expansion of some bryozoan, indicating that the remainder of the shell had been removed before the siphuncle had become imbedded in the mud at the bottom of the sea. The walls of the siphuncle are very thin, and those of the remainder of the shell must have been very fragile or easily dissolved. These siphuncles probably belong to a new genus, as yet too imperfectly known to admit of characterization.

Cyrtocerina madisonensis, Miller.

Cyrtocerina madisonensis is found in considerable numbers in the Hitz layer, at Madison, Indiana, but has not been noticed elsewhere so far.

Orthoceras (Dawsonoceras) hammelli, sp. nov.

(Plate I, fig. 4.)

At the top of the Saluda bed at the Dog Falls, on Saluda creek, in Jefferson county, Indiana, an annulated species of *Orthoceras* occurs in which the annulations, from one point of view, are moderately inclined. One fragment, 53 mm. in length, with 15 annulations, has a width of 19.5 mm. at the top and 17.3 mm. at the base. The annulations are broad and low, and their elevation above the intermediate grooves is scarcely half a millimeter. About 5, sometimes 4 or 6, distinct longitudinal striae occupy a width of 5 mm. near the top. Between each pair is a less distinct striation, and usually two additional striations readily visible only under a lens. In addition to the annulations there are transverse striations, visible only under a lens. About four septa occupy a length equal to the width of the shell.

Orthoceras hammelli occurs at the Wallace Horrell locality, 5 miles south of Hanover. Smaller fragments of the same species occur in the Hitz layer, at the top of the Saluda bed, at Madison, Indiana; and two miles east of Tucker, in Jefferson county, Kentucky, at the overhead bridge, crossing the Southern Railroad. In these specimens the primary longitudinal striations are conspicuously stronger than the intermediate ones.

Specimens of *Orthoceras hammelli* of about the same size as the type specimen occur at numerous localities in the "mottled" limestone, forming the upper part of the Saluda section in many parts of southeastern Indiana. It occurs at this horizon at the railroad cut west of Weisburg, 16 feet above the "shale bed," associated with *Entomis madisonensis, Eurychilina striatomarginata, Leperditia caecigena, Primitia cincinnatiensis,* and *Primitia milleri.* At the creek, east of Ballstown, in Ripley county, Indiana, *Orthoceras hammelli* occurs within 5 feet above the massive *Tetradium* layer, at the base of the Saluda bed. A mile and a half northeast of Enochsburg, in Franklin county, a specimen was found loose at the Saluda horizon, 15 feet above Big Salt creek.

A large specimen, 36 mm. in diameter, was found in the Elkhorn bed, at West Milton, Ohio. In this specimen the primary longitudinal striations occur at intervals of about 3 mm. The median secondary striations are inconspicuous, and the intermediate striations can be seen only under a lens.

Compared with *Orthoceras gorbyi,* Miller, the septa are more remote, and the annulations are either directly transverse or only moderately oblique. Compared with *Orthoceras perroti,* the annulations are much less prominent, and the longitudinal striae are never very conspicuous or developed into lamellar expansions.

Orthoceras (Spyroceras) bilineatum-frankfortensis, sp. nov.

(Plate I, figs. 6 A, B.)

South of Glenn creek, at the Crow distillery, 6 miles southeast of Frankfort, Kentucky, the Logana bed, with *Heterorthis clytie,* is well exposed. The underlying cherty limestone, containing *Orthis tricenaria,* is referred by Prof. Arthur M. Miller to the Curdsville bed. This cherty limestone contains a species of *Orthoceras* characterized by low, transverse annulations, rising scarcely half a millimeter above the flat, intermediate grooves. There are 7 annulations in a length of 22 mm. in a specimen about 22 mm. wide. The annulations are crossed by sharp, longitudinal striae,

about 10 or 11 in a width of 5 mm. Between these more prominent striae, single, very fine striae may be seen with a lens. These longitudinal striae are crossed by very much finer but very distinct transverse striae, about 11 in a length of one millimeter.

In *Orthoceras bilineatum*, the longitudinal striae appear to be much more distant. In *Orthoceras clathratum*, the intermediate striae are absent, although the very fine transverse striae are distinct.

Orthoceras (Loxoceras) milleri, sp. nov.

(Plate I, fig. 5; Plate II, figs. 24 A, B.)

Orthoceracone with circular section, and having a small rate of growth, about 7 mm. in a length of 80 mm. in the larger specimen at hand. This specimen, 80 mm. long, has a width of 38 mm. at the top and 31 mm. at the base. The cameras are shallow, 5 occupying a length of 15 mm. near the smaller end of this specimen. The concavity of the septa equals the depth of two and a half cameras. The siphuncle is strongly nummuloidal. At the larger end of the specimen its width at the septum is 7 mm., at the smaller end its width is 6 mm. Within the cameras the width enlarges considerably, equalling 9 mm. at the smaller end. The inner walls of the nummuloidal segments of the siphuncle are lined with a heavy deposit of calcareous material, leaving a narrow central opening at the septa, but there is no evidence of a radiate structure, as in *Actinoceras*. Similar calcareous deposits line the interior of the cameras. The exterior of the casts of these cameras is marked on one side by faint longitudinal lines, of which there are no trace on the exterior surface of the small fragments of the thin test of the phragmocone remaining locally attached to the casts of the interiors of the cameras.

Several specimens of this species were found in the Perryville bed, about 2 miles south of the Crow distillery, east of the road, near the home of Allen McGarvey, on the farm owned by Mrs. Ben Williams. The locality is one mile southeast of McKee ferry, in Woodford county, Kentucky, about 7 miles south of Frankfort. I desire to name this species in honor of Prof. Arthur M. Miller, of Kentucky State University, who has given much attention to the Ordovician rocks of Kentucky, and to whom I am much indebted for information regarding the same.

Orthoceras (Ormoceras?) hitzi, sp. nov.

(Plate I, fig. 3; Plate II, fig. 22.)

Surface smooth when unweathered; in weathered specimens, longitudinal, flat, raised lines make their appearance. These seem to be due to differences in the resisting powers of different parts of the shell to weathering, or to the internal structure, rather than to raised lines marking the inner surface of the shell cone. In some specimens, these striae have a width of one-third of a millimeter. In others, their width is less. The number of longitudinal striations varies usually between 6 and 9 in a width of 5 mm., but greater numbers are found in some specimens. Orthoceracone rather small, gradually tapering. In a specimen 41 mm. long and 15 mm. wide at the larger end, the width at the smaller end is 9.5 mm. In this length there were 19 septa, of medium concavity. The siphuncle is strongly annulated. The bead-like segments equal in width about forty-three hundredths of the width of the shell at its smaller end; at the constrictions where passing through the septa the width of the siphuncle is about half as great. The cross-section of the shell is circular, and the siphuncle is more or less excentric. The septa, as a rule, are symmetrically transverse, but occasionally are oblique to the length of the shell, possibly due to some physical defect of the individual animal. While the siphuncle is constricted in passing through the septa, a thin lamella, having about the same curvature as the septa, appears to cross the bead-like expansions about half way between the septa, and at this elevation, in the upper part of the shell, the casts of the interior of the bead-like expansions appears constricted in a manner somewhat suggestive of *Ormoceras.*

Compared with *Orthoceras mohri,* Miller, and *Orthoceras fosteri,* Miller, the bead-like expansions of the siphuncle are much wider. Compared with *Orthoceras hallanum,* Miller, the bead-like expansions are relatively wider and occupy a much greater part of the width of the shell. Nothing is known of *Orthoceras carleyi,* Hall and Whitfield, beyond the fact that the tube enlarges slowly, there are about 6 or 7 septa within a length equal to the width of the shell, and the specimen was found at Fayetteville, in Brown county, Ohio, probably in the Waynesville bed.

Compared with *Ormoceras crebriseptum,* the exterior surface of the shell appears smooth.

Orthoceras hitzi occurs in the Hitz layer in southern Indiana

and northern Kentucky, west of the Cincinnati geanticline. The type specimens were found at Madison, Indiana. It has been found also on Camp creek in Clark county; at the Dog Falls on Saluda creek, on the road from Hanover to the Landing, on the Hitz road and on the Hanging Rock road at Madison, at the falls on Crooked creek, one mile northeast of Madison on the road to Riker's ridge, at the falls on Razor creek, along the road a mile and a half southeast of Belleview, a mile north of Belleview, two miles south of Poplar ridge, all in Jefferson county, Indiana. Also four miles west of Cross Plains; and one mile west of Ballstown, in the "mottled" limestone, 13 feet above the top of the Bosberg quarry and about 20 feet above the "shale bed," in Ripley county, Indiana. In the mottled limestone, 16 feet above the shale bed, at the railroad cut west of Weisburg, in Dearborn county, Indiana. It occurs at numerous localities between the locality along the railroad two miles east of Tucker, in Jefferson county, and the area east of Pewee Valley, east of Floyds creek, in Oldham county, Kentucky.

Cyrtoceras hitzi, sp. nov.

(Plate I, figs. 7 A, B; Plate II, figs. 23 A,B,C.)

In the Hitz layer at Madison, Indiana, a very small species of *Cyrtoceras* occurs which is characterized by prominent, transverse striae, which are deflected along the ventral line like a letter V, rounded at the base. Laterally, these striae are directly transverse and approximately straight, or at least not conspicuously wrinkled. At the small end of the fragment, 3.3 mm. in diameter, the transverse section is almost circular. At the larger end, 8 mm. in width, the lateral diameter may exceed the dorso-ventral but the dorsal side is not preserved. Along its length of 17 mm. there are 30 transverse striae. At the larger end, there are 7 in a length of 5 mm. The curvature of the shell is moderate, less than 2 mm. on the ventral side of the specimen at hand. The number of septa is approximately the same as that of the transverse striae. The sipho is unknown.

The small curvature of the shell, the sharp transverse striae deflected backward along the ventral line, and the comparative strightness of these striae laterally are the distinguishing characteristics of *Cyrtoceras hitzi.*

Cryptolithus tessellatus, Green

The lowest horizon at which the species long familiarly known

as *Trinucleus concentricus* occurs is the Logana limestone, at Frankfort, Kentucky. *Trinucleus* is not known from the Wilmore and Paris divisions of the Lexington formation, nor from the lower, Greendale division of the Cynthiana formation. At West Covington, Kentucky, *Trinucleus concentricus* occurs as low as 20 feet below the *Triarthrus becki* horizon. At New Richmond, Ohio, it occurs 11 feet below this horizon. At Point Pleasant, it occurs 11 feet below the *Triarthrus horizon*, and also 35 feet below this horizon. Mature specimens occur at the *Triarthrus becki* horizon, and also in the overlying parts of the Fulton layer, at Point Pleasant, Ohio, at Ivor, Kentucky, and elsewhere along the Ohio and lower Licking rivers. From this level, it ranges through the Economy member and as far as the middle of the Southgate member of the Eden formation, in Ohio, Indiana, and northern Kentucky. It it abundant in the Eden west of Falmouth, Kentucky. A few specimens, associated with *Leptaena gibbosa*, occur in the lower Eden north of Boyd. A short distance northeast of the railroad station, at Ford, *Trinucleus* occurs in an argillaceous limestone, associated with *Ceratopsis intermedia*. It occurs frequently in the Rogers Gap bed, in the lower Eden, between Sadieville and Rogers Gap. At Sparta, it is common above the railroad level, in strata associated with *Prasopora contigua, Eridotrypa mutabilis, Eridotrypa briareus, Ceratopsis intermedia, Primitia bivertex,* and other fossils indicating a horizon beneath the typical Eden. It occurs in the lower Eden east of Hatton, west of Lawrenceburg, and at the top of the new branch of the Southern railroad, a short distance beyond the junction a mile and a half southeast of Harrodsburg. While the exact stratigraphy of most of these localities has not been determined as yet, it is known that the vertical range of *Trinucleus concentricus* diminishes rapidly southwards, amounting to only a few feet at the more southern localities. This may be due in part to a thinning of some of the lower Cincinnatian strata southwards.

An article entitled *Synopsis of the Trilobites of North America* was published by Dr. Jacob Green in the *Monthly American Journal of Geology and Natural Science*, volume 1, No. 12, at Philadelphia, in 1832. This number should have appeared in June, and it is so dated, but the publisher having become bankrupt, the editor was forced to publish the last number at his own expense. Since a letter from Blountsville, Tennessee, dated August 3, 1832, is noted on page 565, and travel at that time was slow, it is scarcely likely

that the number as a whole appeared before the close of September of that year. The article on North American trilobites begins on page 558. A break occurs at the close of this article ,on page 560, and it would have been possible to distribute the earlier pages of this number, evidently printed before the trouble with the publisher became serious (page 566), without awaiting the completion of the number, but there is no evidence that this was done.

Cryptolithus tessellatus, Green, published on page 560, evidently is the same species as *Trinucleus concentricus,* and of this there never has been any doubt. The generic characteristics, considering the date of publication, are clearly indicated. The genus and species were founded upon a specimen collected by Hall from the slates of the Lorraine beds at Waterford, New York, and still in the possession of Hall at the time of publication of volume 1, *New York Paleontology.*

The same specimen was used by Prof. Amos Eaton in describing *Nuttainia concentrica,* although in this description the Trenton locality at Glennsfalls is mentioned first. The description appears on page 33 of the second edition of Eaton's *Geological Text book,* dated June 15, 1832. Unfortunately, the date of a preface is no indication of time of publication of a book, beyond the fact that the latter usually is later. There is no doubt that Green's *Monograph of North American Trilobites,* dated October 1, 1832, appeared later than Eaton's Geological Text book, but on page 88 of his *Monograph* Green states the genus *Cryptolithus* was proposed before the appearance of Eaton's work, evidently in his *Synopsis,* published in the *Monthly American Journal.* That this is possible is shown by the fact that some geological libraries contain copies of the *Monthly American Journal of Geology and Natural Science* which terminate with the close of Green's Monograph, and do not contain the following pages. One of these copies is in the Library of the Walker Museum, at Chicago University, one of the very rare complete copies also being present.

There is no question that the genus *Nuttainia* was founded upon the species usually called *Trinucleus concentricus,* and there is no confusion in the generic description, as the following quotation from Eaton's text-book will show:

> *Nuttainia.* Head in three lobes, the middle one most prominent; the two lateral lobes, sub-hemispherical or sub-quadrantal: the whole head bordered anteriorly with a punctured fillet; body distinctly three lobed, middle lobe subcylindric, and not so broad as the side lobes.

I am unable to see why the fact that Eaton incorrectly referred a glabellar fragment of *Homolanotus dekayi* to *Nuttainia* should invalidate his genus. The validity of his genus must rest solely upon the value of the generic distinctions proposed, the species selected as type, and the relative date of the publication of the genus.

Hall's testimony that *Nuttainia* was established before *Cryptolithus* (*New York Paleontology*, vol. 1, p. 235) is invalidated by the fact that he lists only Green's *Monograph*, not his *Synopsis* in the *American Journal of Geology and Natural History*, even 15 years after the publication of the latter, although both copies of the Journal in the Walker Museum library are from the original Hall library. Moreover, in 1842, in the *Report of the Second District* by the New York Geological Survey, p. 390, Prof. Ebenezer Emmons uses the term *Trinucleus tesselatus*, Green, rather than *Trinucleus concentricus*, Eaton.

I suspect that Green's claim of priority for *Cryptolithus tesselatus* is correct, although at this late date positive proof appears to be lacking. But one thing at least is certain, if the term *Cryptolithus* has priority, then the specific term *tesselatus* also has priority. The combination *Cryptolithus concentricus* is inadmissable.

Regarding the term *Trinucleus*, which has become so firmly established, it can scarcely be said to have been adequately described by Lhwyd, in 1698. It was Sir R. I. Murchison who first gave this term a generic significance, in his work on the Silurian System, in 1839, seven years after the publication of the generic terms proposed by Green and Eaton. The ready acceptance of this term by American authors could have been due only to the great prestige of Murchison and a complete ignorance of Lhwyd's article. Certainly, it was an injustice to the American authors, to retain the term Trinucleus, after its extremely inadequate description became known.

Calymene platycephala, sp. nov.

(Plate II, fig. 7.)

In the Saltillo limestone, at Clifton, Tennessee, there is found a species of *Calymene* with a flattened cephalon. The middle part of the cephalon here figured belongs to the Hall collections in the American Museum of Natural History, in New York City, and is numbered 1409. The anterior part of the glabella and that part

of the anterior border of the cephalon which lies between the facial sutures, have straightened outlines. The anterior pair of furrows limiting the glabellar lobes is short and rather indistinct. The second and third pair are distinct but shallow. The nuchal furrow and its extension across the posterior part of the fixed cheeks are still more distinct, but much less conspicuous than in most species of *Calymene*. The grooves limiting the glabella are broad and shallow. The convexity of the glabella above these grooves does not exceed 2 mm., the border of the cephalon anterior to the glabella is not turned up but lies in about the same plane as the lateral margins of the cephalon. The shell appears smooth to the unassisted eye, but under a strong magnifier is minutely dotted with lighter colored spots. The postero-lateral ends of the fixed cheeks and all of the movable cheeks are absent.

A pygidium found in the same strata and at the same locality (plate III, fig. 21) may belong to this species. There is a strong axial lobe, with about 6 segments, and an undivided posterior portion. The lateral lobes are divided into 6 segments, with a faint indication of a seventh. The groove limiting the axial lobe curves around its posterior end and separates it from the posterior margin of the pygidium. The lateral margins are deflected sharply downwards, the width of this deflected margin narrowing posteriorly, and disappearance along the median parts, behind the axial lobe. A ridge, interrupted at the furrows between the pleural segments, occurs along the line of deflection.

This species evidently is closely related to *Calymene christyi*, from the lower part of the Waynesville bed, near Oxford, Ohio.

Calymene senaria, Conrad.

(Plate II, fig. 14.)

In the American Museum of Natural History, in New York City, there is a specimen from the Trenton at Middleville, New York, which is labelled as *Calymene callicephala*, and numbered 843-7. The length of the specimen is about 59 mm.; of this, 15 mm. belong to the cephalon, 31 mm. to the thorax, and almost 14 mm. to the pygidium. The width of the thorax immediately behind the head is 30 mm., narrowing gradually to about 21 mm. toward the pygidium. The most striking feature of this specimen is the nasute outline of the anterior part of the cephalon. This

nasute border extends fully 4 mm. forward from the anterior border of the glabella. Viewed from the side, it does not appear strongly retrorse, as in the specimens from the Waynesville bed or from the Maysville formation. Of the cephalon, only the cast of the lower side of the chitinous integument forming the upper surface of the cephalon is preserved, but this is sufficient to indicate the chief characteristics of the specimen as described above. Specimens of this type have been identified by Clarke with *Calymene senaria,* Conrad. In the specimen at hand, the postero-lateral outlines of the cephalon, including the genal spines, are not well preserved, but there is no reason to believe that they differ essentially from the form figured as *Calymene senaria* by Clarke, in the *Paleontology of Minnesota,* vol. 3, part 2, p. 700, in 1897. Since this figure is based on a cast of the original specimen, it must be authentic.

Calymene abbreviata, sp. nov.

(Plate III, fig. 17.)

In the upper part of the Greendale bed, at the railroad cut a mile south of Rogers Gap, Kentucky, at the telegraph pole marked as 61 miles south of Cincinnati, a species of *Calymene* occurs which is characterized by the straightened, truncated anterior margin of the glabella. The anterior margin of the fixed cheek is more prominent and abrupt. The anterior border of the cephalon is somewhat flattened, and, owing to the truncation of the anterior margin of the glabella, appears a little more remote from the latter than in most other species. A little antero-lateral to the lateral extremities of the frontal lobe of the glabella, the anterior border of the cephalon presents on each side a low blunt elevation. In consequence, an anterior view of the border appears slightly concave above.

Calymene callicephala, Green.

Calymene callicephala was described by Dr. Jacob Green in an article on North American Trilobites, published in the *Monthly Journal of Geology,* in 1832. The type, located at that time in the Philadelphia Museum, the present location of which however, is unknown, was labelled as coming from Hampshire, Virginia. Hampshire is one of the northeastern counties of West Virginia, bordering on the Potomac river, and is not known to contain any Cincinnatian rocks. This type is represented by cast No. 2 of

the set accompanying Green's *Monograph of North American Trilobites.* This cast certainly does not represent the common trilobite of the Cincinnati group, as exposed at Cincinnati, Ohio. if, indeed, it correctly represents any species whatever. Only the posterior and middle pairs of the lateral lobes of the glabella are indicated. There is no trace of the anterior pair of lobes. It is not probable that any species with these characteristics exists. The front of the glabella should extend in front of a line connecting the anterior parts of the palpebral lobes. Moreover, there is an even slope from the front of the glabella to the anterior margin of the cephalon, while there should be a deep depression here, defining the anterior margin of the glabella, and separating it from the anterior portion of the cephalon. The nasute anterior outline of the cephalon is not as strongly pronounced as in the nasute Calymenes from the Trenton of New York. As a matter of fact, there are specimens of *Calymene* from the vicinity of Cincinnati, which have an equally triangular outline in case of the cephalon, but in none of these are the anterior lobes of the glabella, nor the still more anterior frontal lobe of the glabella, absent.

It is evident from the original description that Green was impressed by the anterior attenuation of the cephalon, in other words, by its nasute outline; and by the absence of the anterior part of the glabella, as found in *Calymene blumenbachii.* His statement that the oculiferous tubercles are rather lower down on the cheeks than usual does not describe the Cincinnatian form, whatever this expression may mean.

The specimens in the cabinet of the New York Lyceum and in that of J. P. Wetherill, from the vicinity of the Miami river, near Cincinnati, Ohio, and those from Indiana, correlated with the Hampshire type by Green in his original description undoubtedly belong to the same type as the series from Cincinnati described by Meek as *Calymene senaria,* but if the type ever be found it may turn out to belong to an entirely different horizon.

Calymene meeki, nom. nov.

(Plate III, fig. 18.)

For the species so well described by Meek from the Cincinnatian rocks of Ohio, as *Calymene senaria,* the term *Calymene meeki* is here proposed. As types, the large specimens from the Fairmount bed, with a rather extended posterior outline of the cephalon, resulting in acute genal angles are chosen.

Calymene meeki — retrorsa.

(Plate III, fig. 19.)

In the Waynesville bed, a form of *Calymene meeki* occurs which differs chiefly in the narrower posterior width of the cephalon, resulting in more obtuse genal angles, inclined to be more or less rounded toward the tip. The anterior border of the cephalon is more strongly reflexed, bringing it closer to the anterior margin of the glabella. The specimen figured was obtained in the Clarksville division of the Waynesville bed, east of Dunlapsville, Indiana, half a mile above the mouth of Silver creek. It is doubtful whether it will be possible to differentiate the Waynesville specimens from those in the Maysville, but the present is at least an attempt.

Calymene is rare in the upper part of the Richmond formation, from the Liberty to the Elkhorn, but occasional specimens may be found. These usually are rather small.

Dalmanites carleyi — rogersensis.

A species of *Dalmanites,* very closely allied to *Dalmanites* (*Pterygometopus*) *carleyi,* occurs in the lower part of the Eden section between Rogers gap and Sadieville; about ten feet above the railroad track at the first large exposure west of bridge 54, west of Million tunnel, in Madison county; and at the cut east of Hatton; all in Kentucky. Compared with *Dalmanites carleyi,* from the Fairmount bed at Cincinnati, Ohio, the Eden specimens differ chiefly in their larger size, the cephalon attaining a width of 20 mm., while the cephalon of the Fairmount specimens usually do not exceed 15 mm. That part of the glabella which lies posterior to the frontal lobe is more elongate and slightly less constricted at the nuchal segment. The pygidium also is closely similar to that of the Fairmount form. The chief interest in these Eden specimens consists not in their distinctness from the Fairmount species, but in their very close relationship, increasing the number of species in the Rogers Gap fauna, which may be regarded as precursors of the Fairmount fauna.

Pasceolus camdenensis, sp. nov.

(Plate II, fig. 6.)

In the American Museum of Natural History, in New York City, there is a specimen of *Pasceolus* which is labelled as coming

from Camden, Ohio. It is almost spherical, the vertical diameter being 30 mm., and the transverse diameter nearly 28 mm. Forty-five to fifty plates lie along a line encircling the specimen horizontally. The plates usually are hexagonal in outline, and are arranged in crossing diagonal rows, but locally the outline may be more nearly pentagonal and occasionally five plates may appear to meet at a central point. Five plates occur in a length of 10 mm. along the diagonal lines, varying to 7 in the same length where they are of smallest size. The exposed surfaces of the plates are convex. The nature of the impressions which would be left by these plates upon the matrix filling the cavity of the fossil is unknown. The specimen is not pointed at one end, as though for attachment to some object, as in case of the species *Pasceolus halli.*

Pasceolus halli possesses convex plates bent so as to be slightly depressed towards the angles and elevated toward the sides. Fragments of an unknown species of *Pasceolus* from Anticosti, presenting the same form of plates, possess a series of minute granules visible only under a higher magnifier. These granules are arranged in diagonal series diverging on each of the radial elevations, just mentioned, toward the depressed angles of the plates. This ornamentation suggests that this division of *Pasceolus* may belong to Cystids.

Pasceolus globosus, the type of the genus *Pasceolus,* belongs to the group of species characterized by the presence of somewhat concave plates, often marked by six stellate radiating lines of depression extending from the center of each plate toward the angles.

It is not certain that the group typified by *Pasceolus halli* is congeneric with *Pasceolus globosus. Pasceolus darwini* and *Pasceolus claudei* belong to the *Pasceolus globosus* group. The plates of *Pasceolus gregarius* and *Pasceolus intermedius* have not been described.

Labechia (?) corrugata, sp. nov.

(Plate I, fig. 11.)

In the Whitewater bed, along Dutch creek, near Wilmington, Ohio, an encrusting form of some Stromatoporoid occurs which differs from any of the species described hitherto from Cincinnatian rocks in the irregularity of the nodules or ridges ornamenting its

surface. As in other species described from the same rocks, the surface is ornamented by small granules or papillae. These are rather coarse, and vary greatly in number and size in different parts of the same specimen, but usually about 3 or 4 occur in a length of 2 mm. In addition to the granules there are nodules, more or less irregular in shape, varying to short ridges, or connected so as partially to enclose small papillate areas from 1.5 to 2 mm. in diameter. In *Alveolites granulosa*, James, *Stromatopora subcylindrica*, James, *Labechia ohioensis*, Nicholson, and *Labechia montifera*, Ulrich, the nodules are large, broad and relatively distant from each other, varying from 4 in a length of 20 mm. to the same number in a length of 30 mm. In *Stromatopora scabra*, the nodules have a regular conical form and are rather regularly distributed, about 5 or 6 in a length of 15 mm. In *Labechia corrugata* from 5 or 6 to 3 irregular noduliferous elevations occur in a length of 10 mm. *Stromatopora indianensis*, James, was described as massive, not incrusting. The thickness of the specimens here described as *Labechia corrugata* is 3 mm. The generic reference of these specimens to *Labechia* is merely owing to the superficial resemblance of these specimens to the various species of Cincinnatian stromatoporoids which at one time or another have been referred to this genus. Probably none of these are congeneric with the type of that genus, *Labechia conferta*.

A large specimen, collected by Dr. George M. Austin, from the same locality, is crossed by irregular, vermiform ridges, distant in some places, more numerous, and more or less intertwining in others. These ridges appear in addition to the coarse papillae and the small irregular nodules characteristic of the species. For this form the term *Labechia* (?) *corrugataglypta* has been selected.

PLATE I.

FIG. 1. *Suecoceras (?) inaequabile,* Miller. Lower end of siphuncle, laterally compressed. From the *Orthoceras fosteri* layer, at the base of the Clarksville division of the Waynesville bed, in the Stony Hollow, northwest of Clarksville, Ohio.

FIG. 2. *Suecoceras (?) inaequabile,* Miller. Lower end of siphuncle. Madison, Indiana, from the Waynesville bed.

FIG. 3. *Orthoceras (Ormoceras?) hitzi.* Smooth orthoceracone, with vertical striae due to weathering. Madison, Indiana, from the Hitz layer, at the top of the Saluda bed.

FIG. 4. *Dawsonoceras hammelli.* Dog Falls, on Saluda creek, southwest of Hanover, Indiana, from the Hitz layer at the top of the Saluda bed.

FIG. 5. *Orthoceras (Loxoceras) milleri.* Orthoceracone, with traces of the smooth shell. Two miles south of the Crow distillery, 7 miles south of Frankfort, Kentucky, from the Perryville bed.

FIG. 6. *Spyroceras bilineatum-frankfortensis.* South of Glenn creek, at the Crow distillery, 6 miles south of Frankfort, Kentucky, from the Logana bed.

FIG. 7. *Cyrtoceras hitzi.* Convex side of cyrtoceracone. *B,* the same, enlarged. Madison, Indiana, from the Hitz layer, at the top of the Saluda bed.

FIG. 8. *Clidophorus.* New species, resembling *Clidophorus neglectus* in outline, but with the posterior umbonal ridge less strongly defined, and with the clavicle directed slightly forward from the beak, limiting a shorter anterior muscle scar. *B,* the same, inverted and enlarged. Clifton, Tennessee, from the Saltillo bed.

FIG. 9. *Opisthoptera concordensis.* Left valve, with the outline not preserved and not known. In the creek bed south of the railroad bridge, east of Concord, Kentucky. From the upper part of the Arnheim bed, five and a half feet below the *Strophomena concordensis* zone, associated with *Streptelasma vagans.*

FIG. 10. *Pterinea (Caritodens) demissa,* Conrad. Left valve. Clifton, Tennessee, from the Arnheim bed.

FIG. 11. *Labechia (?) corrugata.* Dutch creek, northwest of Wilmington, Ohio, from the top of the Whitewater bed.


1
2
3
4
5
6 A
6 B
7 A
7 B
A 8
8 B
9
10
11

PLATE II.

FIG. 1. *Hebertella occidentalis,* Hall. *A,* brachial valve. *B,* pedicel valve, Type specimen illustrated in *New York Paleontology,* vol. 1, plate 32A, by figures 2c, 2k. Cincinnati, Ohio.

FIG. 2. *Hebertella occidentalis,* Hall. *A,* brachial valve; *B,* pedicel valve. Type specimen illustrated in *New York Paleontology,* vol. 1, plate 32 A, by fig. 2e. Cincinnati, Ohio.

FIG. 3. *Catazyga headi-schuchertana,* Ulrich, lateral view. Madison, Indiana, from the Waynesville bed, Madison, Indiana.

FIG. 4. *Rafinesquina declivis,* James. Pedicel valve, enlarged 1.8 diameters. The type specimen described by James. Boyd's station, Kentucky, from the argillaceous limestones beneath the Eden formation.

FIG. 5. *Hebertella sinuata,* Hall. Brachial valve. Type specimen illustrated in *New York Paleontology,* vol. 1, plate 32 B, figs. d, h, k, and plate 32 C, fig. o. Cincinnati, Ohio.

FIG. 6. *Pasceolus camdenensis.* Camden, Ohio.

FIG. 7. *Calymene platycephala.* Clifton, Tennessee, in the Saltillo bed.

FIG. 8. *Hebertella subjugata.* Hall. Brachial valve. Type specimen illustrated in *New York Paleontology,* vol. 1, plate 32 C, fig. 1a. Cincinnati, Ohio.

FIG. 9. *Plectorthis jamesi,* Hall. *A,* Brachial valve, enlarged; *B,* Pedicel valve of the same specimen. Type specimen, illustrated in the *Ohio Paleontology,* vol. 2, plate 1, by figs. 21, 22. Cincinnati, Ohio.

FIG. 10. *Cyclocoelia sordida,* Hall. Brachial valve. Type. Cincinnati, Ohio. Magnified 1.7 diameters.

FIG. 11. *Cyclocoelia ella,* Hall. Type, with 21 plications, belonging to series No. 1506-3, in the American Museum of Natural History, in New York City. Cincinnati, Ohio. Magnified 1.7 diameters.

FIG. 12. *Cyclocoelia ella,* Hall. One of the same series of types, numbered 1056-3, but with 27 plications, approaching *Cyclocoelia sordida-multiplicata.* Cincinnati, Ohio. Magnified 1.7 diameters.

FIG. 13. *Plectorthis equivalvis,* Hall. *A,* Brachial valve; *B,* lateral view. Type, in the American Museum of Natural History, in New York City. Cincinnati, Ohio.

FIG. 14. *Calymene senaria,* Conrad. American Museum of Natural History, in New York City. From the Trenton, at Trenton Falls, New York.

FIG. 15. *Zygospira modesta,* Hall. *A,* Brachial valve, enlarged; *B,* pedicel valve, of the same specimen. Type. Cincinnati, Ohio.

FIG. 16. *Rhynchotrema dentata,* Hall. Brachial valve. Type. From the region of the Cincinnati geanticline, possibly from the Whitewater bed.

FIG. 17. *Lingula modesta,* Ulrich. Frankfort, Kentucky, from the Logana bed.

FIG. 18. *Lingula waynesboroensis.* Three and a half miles northwest of Waynesboro, Tennessee, near the home of W. D. Helton, on Beech creek, in the Saltillo bed.

FIG. 19. *Catazyga uphami-australis.* *A,* brachial valve; *B,* lateral view. High Bridge, Kentucky, near the lower part of the exposures on the road down to the lock, in the Camp-nelson division of the Highbridge formation.

FIG. 20. *Leptobolus lepis-cliftonensis.* *A,* pedicel valve; *B,* cast of interior of pedicel valve; *C,* cast of interior of brachial balve. Clifton, Tennessee, from the Saltillo limestone. Magnified 5 diameters.

FIG. 21. *Conocardium richmondensis.* *A,* lateral view; *B,* cardinal view. Magnified 1.6 diameters. Elkhorn creek, 15 feet below the Brassfield or Clinton bed, in the Elkhorn bed, southeast of Richmond, Indiana.

FIG. 22. *Orthoceras (Ormoceras ?) hitzi.* Vertical section passing obliquely through the siphuncle, crossing the center near the lower end of the specimen. The distinctness of the detail is over-accentuated in the drawing. Madison, Indiana, from the Hitz layer, at the top of the Saluda bed.

FIG. 23. *Cyrtoceras hitzi.* *A,* cross-section near the upper end, the concave side of the specimen not being preserved; *B,* convex or dorsal side; *C,* lateral view of the imperfect specimen. Madison, Indiana, from the Hitz layer, at the top of the Saluda bed.

FIG. 24. *Orthoceras (Loxoceras ?) milleri.* *A,* cross-section, showing relative size of the siphuncle where passing through the septum; *B,* vertical section through the siphuncle, showing strongly nummuloidal segments, as in *Actinoceras.* Two miles south of the Crow distillery, 7 miles south of Frankfort, Kentucky, from the Perryville bed.

ORDOVICIAN FOSSILS.
A. F. FOERSTE.

PLATE II.

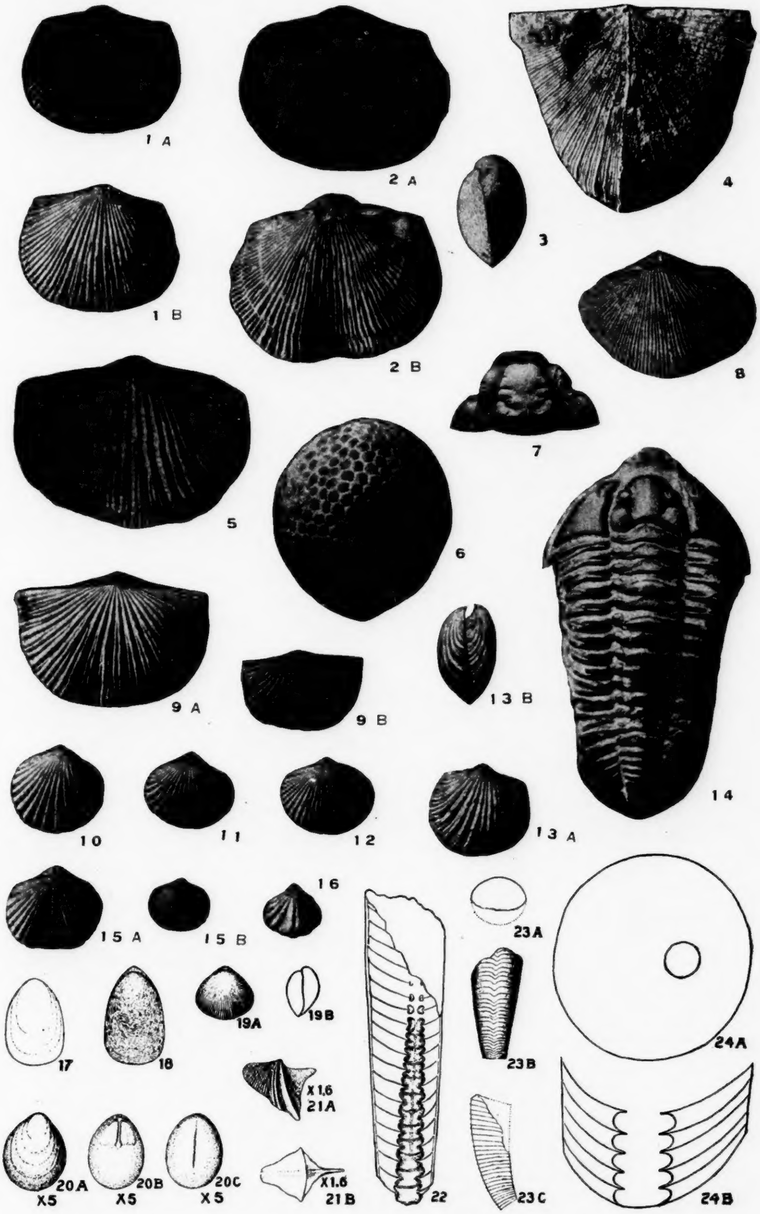


PLATE III.

FIG. 1. *Platystrophia laticosta,* Meek. *A,* brachial valve; *B,* pedicel valve. Cincinnati, Ohio, Fairmount bed.

FIG. 2. *Platystrophia laticosta,* Meek. Brachial valves. From the group of specimens numbered 40479 in the U. S. National Museum, said by R. S. Bassler to be from the Waynesville bed, at Waynesville, Ohio.

FIG. 3. *Platystrophia clarksvillensis.* Brachial valve. Stony Hollow, a mile and a half southeast of the railroad station at Fort Ancient, Ohio, in the lower or Fort Ancient division of the Waynesville bed.

FIG. 4. *Platystrophia clarksvillensis.* Brachial valve. Sewell run, south of the pike from Wilmington to Clarksville, Ohio, in the middle or Clarksville division of the Waynesville bed.

FIG. 5. *Platystrophia cypha,* variety. At the deep railroad cut three miles south of Maysville, one mile north of Summit, Kentucky, in the upper division of the Arnheim bed.

FIG. 6. *Platystrophia acutilirata,* Conrad. Brachial valve. Richmond, Indiana, from the upper part of the Whitewater bed.

FIG. 7. *Platystrophia acutilirata,* Conrad. Pedicel valve. Pennsylvania railroad cut, at Huffman hill, in the eastern part of Dayton, Ohio, in the upper part of the Whitewater bed.

FIG. 8. *Platystrophia acutilirata-prolongata,* James. Richmond, Indiana, from the upper part of the Whitewater bed.

FIG. 9. *Platystrophia* sp. A unique specimen from the *Homotrypa wortheni* horizon at the base of the Elkhorn bed, on Elkhorn creek, three miles southeast of Richmond, Indiana.

FIG. 10. *Orthorhynchula linneyi,* James. Brachial valve. One mile north of Paint Lick, Kentucky, in the upper part of the Fairmount bed.

FIG. 11. *Catazyga headi-schuchertana,* Ulrich. Madison, Indiana, along the Hitz road, west of the railroad incline, in the upper part of the Waynesville bed.

FIG. 12. *Rhynchotrema dentata,* Hall. Richmond, Indiana, in the upper part of the Whitewater bed. Lateral view.

FIG. 13. *Rhynchotrema dentata-arnheimensis.* Lateral view. Along the creek south of Arnheim, Ohio, in the Arnheim bed.

FIG. 14. *Catazyga uphami-australis.* Brachial views. *B,* specimen with a low, broad median elevation; *C,* enlarged view of *A,* the type. High Bridge, Kentucky, in the Camp-nelson bed.

FIG. 15. *Cyclocoelia sectostriata,* Ulrich. Brachial views. *B,* enlarged view of *A.* Cincinnati, Ohio, Fairmount bed.

FIG. 16. *Cyclocoelia crassiplicata.* Cincinnati, Ohio, in the Fairmount bed. Types.

FIG. 17. *Calymene abbreviata.* At mile post 61, one mile south of Rogers Gap, in the Greendale division of the Cynthiana formation.

FIG. 18. *Calymene meeki.* Cincinnati, Ohio, in the Fairmount bed.

FIG. 19. *Calymene meeki-retrorsa.* On Silver creek, east of Dunlapsville, Indiana, in the middle or Clarksville division of the Waynesville bed.

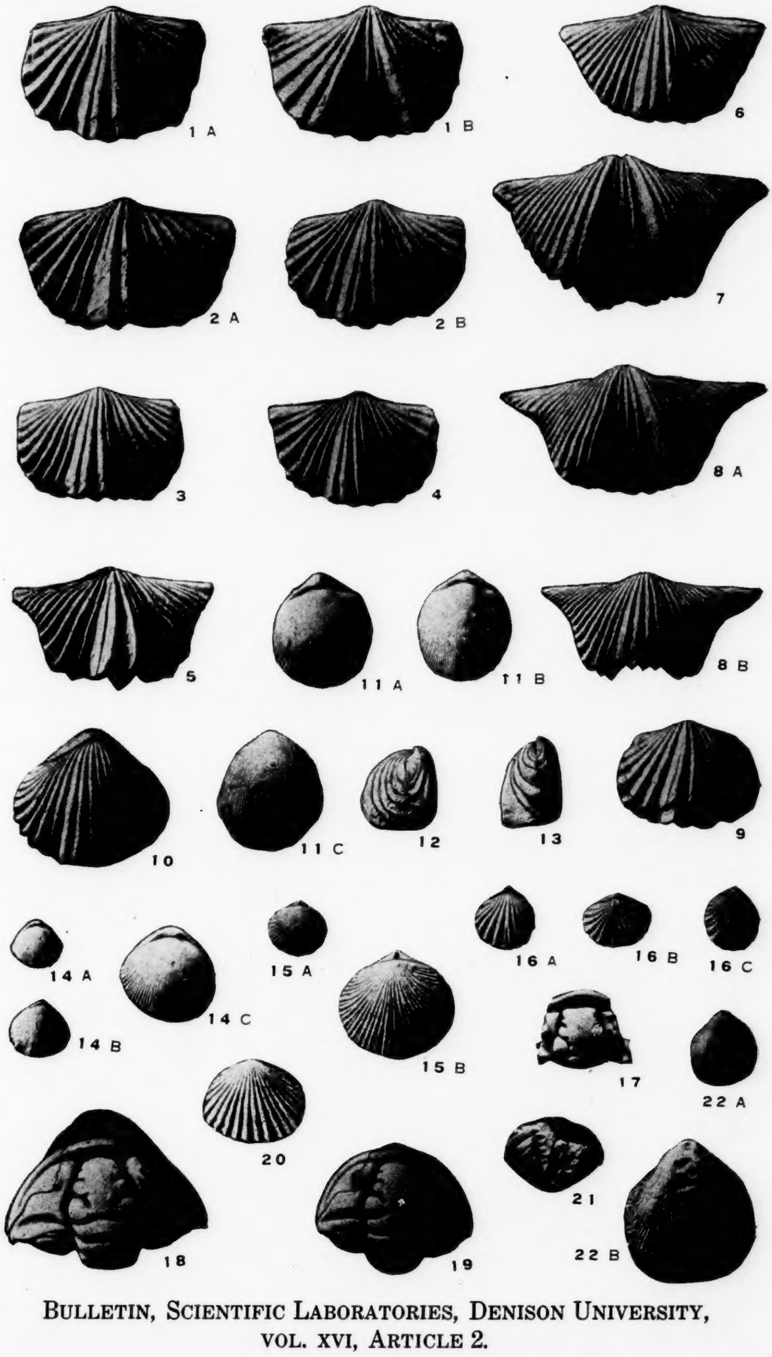
FIG. 20. *Orthorhynchula ?* Unknown brachiopod with simple plications, the four median plications slightly elevated. From a well in the Fulton or Lower Eden, 1 mile south of Lower Blue Lick Springs, Kentucky.

FIG. 21. *Calymene platycephala ?* Pygidium, found at the same horizon as the middle part of the cephalon of *Calymene platycephala.* Clifton, Tennessee, in the Saltillo bed.

FIG. 22. *Schizocrania rudis,* Hall. Upper valve, slightly crushed.. *B,* view of *A,* enlarged. Clifton, Tennessee, in the Saltillo bed.

ORDOVICIAN FOSSILS.
A. F. FOERSTE.

PLATE III.



BULLETIN, SCIENTIFIC LABORATORIES, DENISON UNIVERSITY,
VOL. XVI, ARTICLE 2.

PLATE IV.

FIG. 1. *Platystrophia colbiensis-precursor.* Brachial valve. At mile post 627, between Colby and Winchester, Kentucky, in the Greendale division of the Cynthiana formation.

FIG. 2. *Platystrophia colbiensis.* *A,* brachial valve; *B,* pedicel valve. Along the railroad, a mile and a half southwest of Carlisle, Kentucky, in the Greendale division of the Cynthiana formation.

FIG. 3. *Platystrophia colbiensis-mutata.* Brachial valves. Five miles west of Winchester, Kentucky, along the railroad to Colby, in the Greendale division of the Cynthiana formation.

FIG. 4. *Platystrophia profundosulcata-hopensis.* Brachial valve. Cincinnati, Ohio, in the Mount Hope bed.

FIG. 5. *Platystrophia crassa,* James. *A,* cardinal view; *B,* brachial valve. Cincinnati, Ohio, near the middle of the Fairmount bed.

FIG. 6. *Platystrophia unicostata,* Cumings. Brachial valve. Above the conspicuous *Platystrophia ponderosa* horizon in the Bellevue bed, near foot of road from New Hope church to Willard branch of the south fork of Laughery creek, in Ohio county, Indiana.

FIG. 7. *Platystrophia cypha-conradi.* Brachial valves. Along the Bardstown pike, half a mile south of Smithville, in Bullitt county, Kentucky, in the Arnheim bed.

FIG. 8. *Platystrophia acutilirata-inflata,* James. *A,* cardinal view; *B,* brachial valve. Types, No. 1561, from the Walker Museum of Chicago University. This form occurs in the upper part of the Whitewater beds at Richmond, Indiana. James collection.

FIG. 9. *Platystrophia acutilirata,* Conrad. Brachial valve.

FIG. 10. *Platystrophia cypha,* James. *A,* brachial valve; *B,* anterior view. Warren county, Ohio. Type, No. 2326, from the Walker Museum at Chicago University. James collection.

FIG. 11. *Platystrophia cypha-versaillesensis.* Brachial valves. Versailles, Indiana, from the Liberty bed.

FIG. 12. *Platystrophia cypha,* James. Mount Sterling, Indiana, from the Bellevue horizon, immediately over the conspicuous *Platystrophia ponderosa* horizon.

FIG. 13. *Platystrophia cypha-versaillesensis.* Intermediate between the forms *conradi* and *versaillesensis.* North of Hogan creek, on the road from Moores Hill to Holman, Indiana, about 25 feet below the *Hebertella insculpta* horizon, in the Blanchester division of the Waynesville bed, associated with an abundance of *Leptaena richmondensis.*

FIG. 14. *Platystrophia cypha-conradi.* Half a mile south of Smithville, Kentucky, in the Arnheim bed. Brachial valves.

PLATE IV.

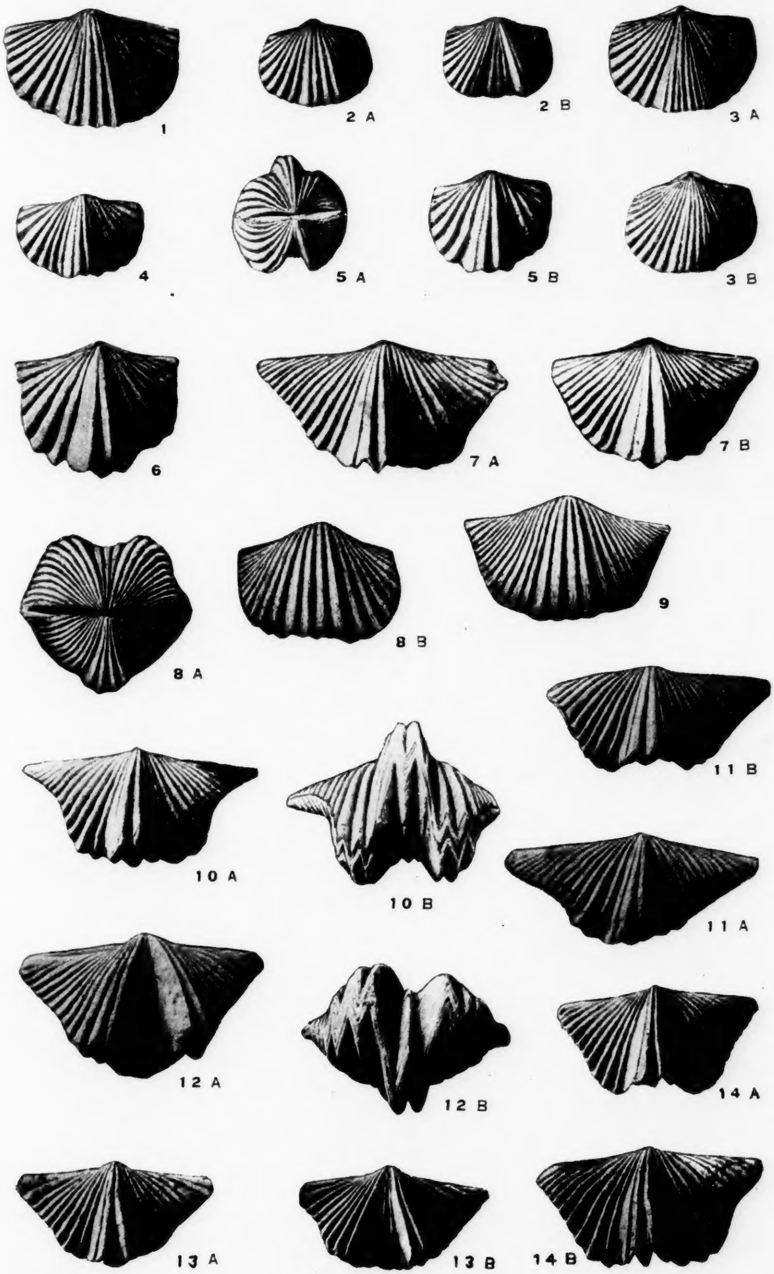

1
2 A
2 B
3 A
4
5 A
5 B
3 B
6
7 A
7 B
8 A
8 B
9
11 B
10 A
10 B
11 A
12 A
12 B
14 A
13 A
13 B
14 B

PLATE V.

FIG. 1. *Trematis punctostoriata,* Hall. Clifton, Tennessee, from the Saltillo bed.

FIG. 2. *Trematis fragilis,* Ulrich. Figured in *Ohio Paleontology,* vol. 2, plate 1, fig. 9, as *Trematis punctostriata.* No. 102 of the James collection at Chicago University. Cincinnati, Ohio.

FIG. 3. *Trematis fragilis,* Ulrich. Lower valve, showing the pedicel scar. Cincinnati, Ohio.

FIG. 4. *Trematis fragilis,* Ulrich. Upper valve. Cincinnati, Ohio.

FIG. 5. *Lingula covingtonensis,* Hall and Whitfield. Interior of valve, enlarged 1.8 diameters. West Covington, Kentucky, between 25 and 50 feet above low water in the Ohio river, from the strata beneath the two foot crinoidal layer which underlies the Fulton bed.

FIG. 6. *Lingula covingtonensis,* Hall and Whitfield. Interior of valve, enlarged 2 diameters. Frankfort, Kentucky, from the Logana bed.

FIG. 7. *Lingula waynesboroensis.* Brachial valve, with the tip of the pedicel valve exposed at the top, enlarged 2 diameters. Three and a half miles northwest of Waynesboro, Tennessee, near the home of W. D. Helton, on Beech creek.

FIG. 8. *Crania granulosa-cumberlandensis.* Upper valve, enlarged 2 diameters. A mile and a quarter southwest of Cumberland City, Tennessee, along the railroad south of the crossing of the Erin pike, from the Stones River group.

FIG. 9. *Leptaena tenuistriata?* Pedicel valve. *B,* the same, with a part of the anterior margin restored; enlarged. Clifton, Tennessee, from the Saltillo bed.

FIG. 10. *Hebertella alveata-richmondensis.* Type. Brachial valve. Richmond, Indiana, from the top of the Whitewater bed, associated with *Rhynchotrema dentata.*

FIG. 11. *Platystrophia cypha,* James. Type. Cardinal view. No. 2326, James collection, Chicago University. Warren county, Ohio.

FIG. 12. *Rafinesquina declivis,* James. Pedicel valves. *A,B,* the type. *B,* lateral view, showing deflection of the sides due to pressure. *C,* triangular shell with the margin only moderately deflected. *D,* another specimen of the same series presenting the normal outline, except at the cardinal angles, which usually are more nearly rectangular. Series No. 2392. James collection, at Chicago University. Boyd's station, Kentucky, from the strata underlying the Eden formation.

FIG. 13. *Rafinesquina winchesterensis.* *A,* brachial valve; southwest of Antioch church, west of the Million tunnel, in Madison county, Kentucky. *B,* brachial valve, interior; west of Winchester, Kentucky. *C,* pedicel valve, south of Pleasant Valley, Kentucky. From the Greendale bed.

FIG. 14. *Rafinesquina winchesterensis-filistriata.* Interior of brachial valve. Thirteen and a half miles northeast of Paris, Kentucky, measured along the railroad to Carlisle. From the Greendale bed.

FIG. 15. *Rafinesquina winchesterensis-filistriata.* *A,* pedicel valve. *B,* brachial valve of the same specimen. Clays Ferry, on the Kentucky river, in Madison county, Kentucky. From the Greendale bed.

FIG. 16. *Plectorthis dichotoma* (?). *A,B,* brachial valves. *C,D,* pedicel valves. West of Dillsboro station, Indiana, about 10 feet below the *Platystrophia ponderosa* beds, in the upper Fairmount.

FIG. 17. *Hebertella alveata-richmondensis.* Brachial valve. Richmond, Indiana, from the same horizon as the type represented by figure 10 on this plate, but with the shell moderately prolonged at the hinge-line. Upper part of Whitewater bed.

ORDOVICIAN FOSSILS.

A. F. FOERSTE.

PLATE V.

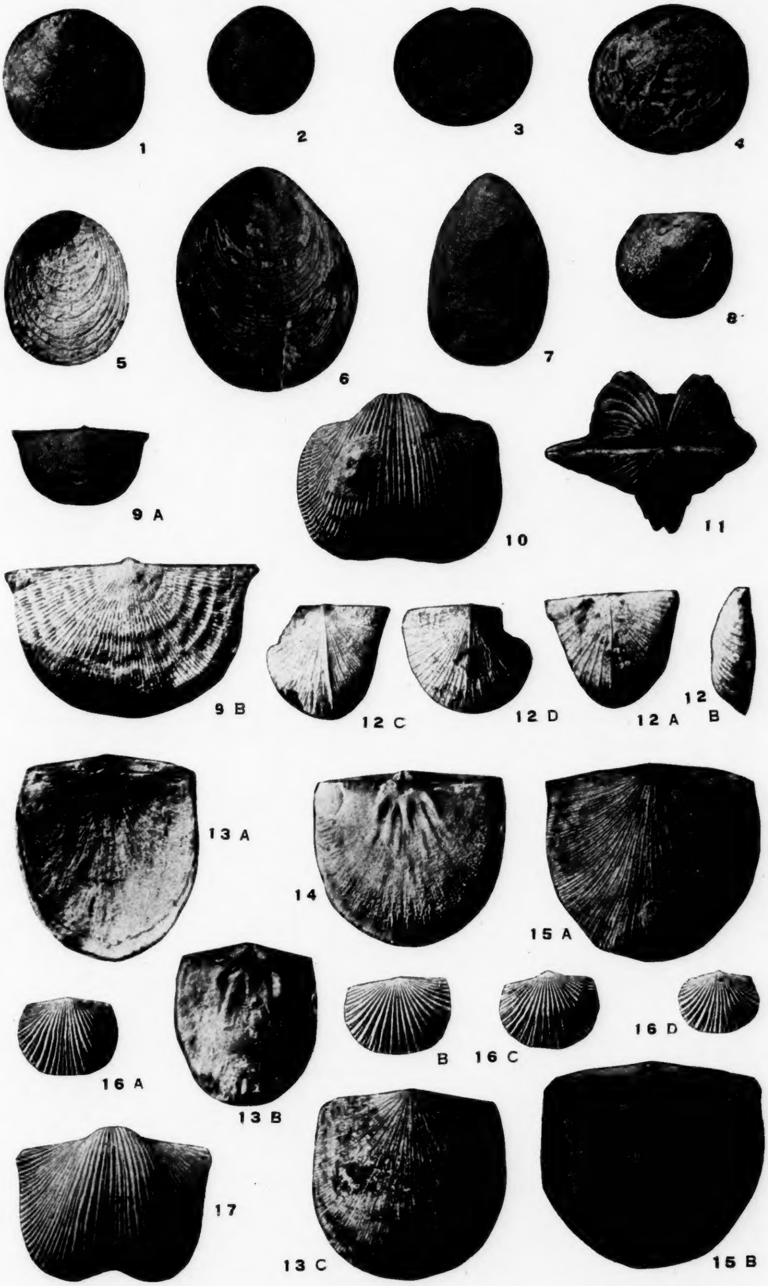


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PLATE VI.

FIG. 1. *Plectorthis neglecta,* James. *A,D,* brachial valves. *B,* pedicel valve. *C,* view of hinge area. Series of types, James collection, No. 2399. Chicago University. *E,* interior of pedicel valve. James collection, No. 127. Cincinnati, Ohio, from Mount Hope bed.

FIG. 2. *Plectorthis equivalvis-pervagata.* Primary plications of moderate prominence. Brachial valve. Gurley collection, No. 8127, Chicago University. Cincinnati, Ohio, from the Fairmount bed.

FIG. 3. *Plectorthis equivalvis-latior.* Primary plications more prominent, varying toward *Plectorthis fissicosta.* Brachial valve. Gurley collection, No. 8127, Chicago University. Cincinnati, Ohio, from the Fairmount bed.

FIG. 4. *Plectorthis fissicosta,* Hall. Wider grooves between the primary plications, the secondary plications added a considerable distance from the beak, and occupying a distinctly lower position. Brachial valve. Gurley collection, No. 8127, Chicago University. Cincinnati, Ohio, from the Fairmount bed.

FIG. 5. *Plectorthis plicatella,* Hall. Brachial valves. Gurley collection, No. 8127, Chicago University. Cincinnati, Ohio, from the Fairmount bed.

FIG. 6. *Cyclocoelia sordida-multiplicata.* With 29 to 34 plications. *A,* brachial valve. *B,* pedicel valve. Gurley collection, No. 8115. *C,* brachial valve, Chicago University. *D,* pedicel valve, apparently a narrow, pathological specimen. James collection, No. 130, Chicago University. Cincinnati, Ohio, from the Fairmount bed.

FIG. 7. Enlarged views of the preceding.

FIG. 8. *Plectorthis sordida,* Hall. *A,* brachial valve. *B,* same, enlarged. Cincinnati, Ohio, from the Fairmount bed.

FIG. 9. *Cyclocoelia crassiplicata,* sp. nov. *A,C,* brachial valves. *B,* pedicel valve. Cincinnati, Ohio, from the Fairmount bed.

FIG. 10. Enlarged views of the preceding.

FIG. 11. *Platystrophia morrowensis,* James. *A,* brachial valve. *B,* same, enlarged. Type, James collection, Chicago University. Warren county, Ohio, from the upper part of the Corryville bed.

FIG. 12. *Platystrophia morrowensis,* James. Form with longer hinge-line named *Platystrophia similis* by Ulrich. *A,* pedicel valve. *B,* same, enlarged. James collection, Chicago University. Probably found associated with the preceding.

FIG. 13. *Platystrophia acuminata,* James. *A,* pedicel valve. *B,* same, enlarged. Type, James collection, No. 1562, Mount Auburn, at Cincinnati, Ohio, probably from the Mount Auburn bed.

FIG. 14. *Platystrophia annicana,* James. *A,* pedicel valve. *B,* anterior view of same. *C,* brachial valve of another specimen. Types. James collection, No. 84, Chicago University. Blanchester, Ohio, from the upper or Blanchester division of the Waynesville bed.

FIG. 15. *Platystrophia profundosulcata,* Meek. *A,B,* brachial valves. *C,* anterior view. James collection, No. 186, Chicago University. Labelled as types, but not the specimens figured by Meek. Cincinnati, Ohio, from the Fairmount bed.

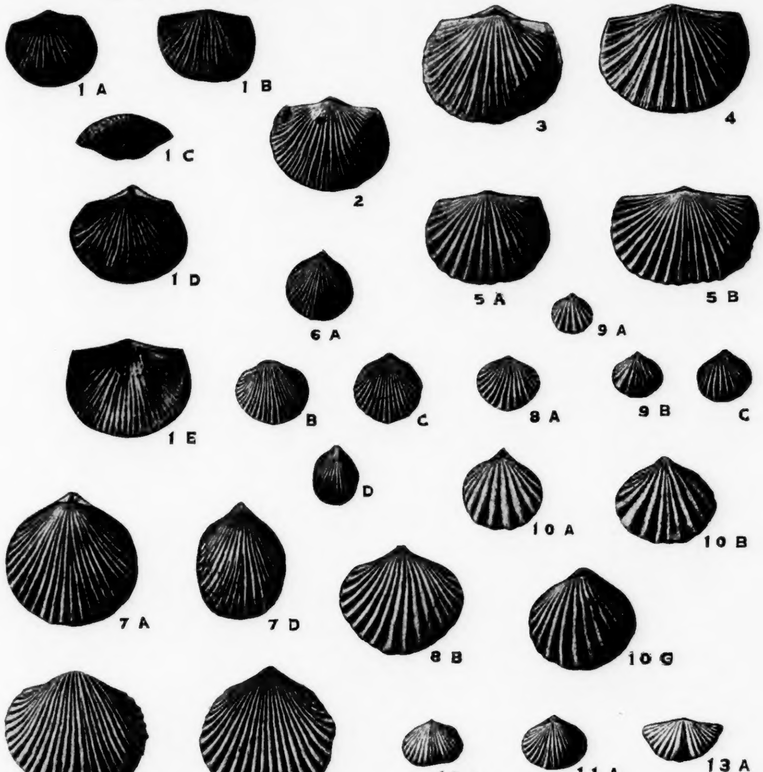
FIG. 16. *Zygospira cincinnatiensis,* Meek. *A,* pedicel valve. *B,* brachial valve. James collection, No. 164, Chicago University, from a series of specimens marked as types, but differing apparently from the specimen described by Meek. Cincinnati, Ohio, from the Fairmount bed.

FIG. 17. *Plectorthis equivalvis,* Hall. *A,* lateral view. *B,* pedicel valve of the same enlarged. Closely resembling the type described by Hall, but broader. Cincinnati, Ohio, from the Fairmount bed.

ORDOVICIAN FOSSILS.

A. F. FOERSTE.

PLATE VI.



BULLETIN, SCIENTIFIC LABORATORIES, DENISON UNIVERSITY, VOL. XVI, ARTICLE 2.

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THE ABANDONED SHORELINES OF THE OBERLIN QUADRANGLE, OHIO[1]

FRANK CARNEY

Many students have given attention to the shifting series of lakes that followed up the retreating Wisconsin ice sheet. The broader questions involved in this history have been investigated and the general outlines of the succeeding lake stages, and their individual overflow channels, have been mapped.[2] In some parts of the Great Lakes' basin more detailed mapping has been done.[3] In the Maumee Valley of Ohio, G. K. Gilbert has studied in considerable detail the raised beaches.[4] On the Oberlin sheet the only work heretofore published is that (1) of E. E. Wright,[5] who located several beaches at scattered points, thus getting enough of evidence to make a very general map; and (2) of J. S. Newberry, who briefly explains Wright's map.[6]

The surface features of the Oberlin sheet (plate VII) have not been altered much during post-glacial times. The area has a general and quite uniform northward slope, declining from an altitude of 850 feet to 573 feet, the level of Lake Erie. The drainage of practically the whole sheet focuses into one major stream, the Black river. A narrow strip on the west side is controlled by Beaver creek. The course of Black river, south of the Warren shoreline, reflects preglacial topography. It follows the axis of a depression which was sufficiently deep and broad to form a bay in each of the three lake stages; this irregularity of shoreline was least in the Warren stage and greatest in the Maumee stage.

The stratigraphy of the sheet is obvious both in the topography and in the resulting outline of the high-level lakes. Throughout

1 Read at the meeting of the American Geological Society, Boston, December, 1909, with the permission of the State Geologist of Ohio. The author is responsible for the facts given.

2 Whittlesey, Charles, *The American Journal of Science*, vol. X (1850), pp. 31-39. Taylor, F. B., *Bull. Geol. Soc. Am.*, vol. VII (1897), pp. 31-58. Leverett, F., *Monograph XLI*, U. S. Geological Survey (1902), pp. 710-775.

3 Alden, W. C., *The Chicago Folio*, No. 81, U. S. Geol. Survey, 1902. *The Milwaukee Special Folio*, No. 140, U. S. Geol. Survey, 1906. Goldthwait, J. W., "The Abandoned Shorelines of Eastern Wisconsin," *Wis. Geol. and Nat. Hist. Survey*, (1907), pp. IX-134. Atwood, W. D., and Goldthwait, J. W., "Physical Geography of the Evanston-Waukegan Region", *Illinois State Geol. Survey*, Bulletin No. 7, (1908), pp. 28-69.

4 *Geological Survey of Ohio*, vol. I, (1873), pp. 535-56.

5 *Geological Survey of Ohio*, vol. II, (1874), map opposite p. 58.

6 *Ibid*, pp. 207-8.

two-thirds of the sheet's area, the Berea sandstone formation is either on or very near the surface. Preglacial weathering of the Berea cut it back towards Elyria, making a depression followed now by the Black river. This depression is confined northward, and is bounded, by sandstone outcrops near Avon Center and Sheffield Junction; several outliers of the Berea extend southwestward from Sheffield Junction. For many miles south of this escarpment the Berea sandstone has a very shallow covering of drift.

Wherever a shoreline coincided with the outcropping Berea, the waves produced a load of stand for transportation. Beach ridges and other shore forms were constructed more quickly than when the waves worked only on shale or on glacial drift. In every case the most conspicuous beaches reflect this rock influence. A similar influence is seen also in the islands, formed by outliers of the Berea sandstone, and in barriers that were constructed in the shallow water overlying outliers that did not form islands.

THE MAUMEE SHORELINE

At most points where this shoreline has been studied in Ohio, it consists of two beach ridges, separated by a vertical difference of ten to twenty feet; the upper shoreline has an altitude of about 770 feet. These two ridges generally are present in the Oberlin sheet.

A broad embayment characterized the Maumee shoreline in the Oberlin quadrangle. This bay, during the higher Maumee stage, extended about four miles southward from Elyria.

Upper Maumee stage.—Commencing on the western edge of the sheet, for nearly five miles I have indicated a single beach for the Maumee stage. In this distance the shoreline is not very well developed. The glacial drift does not appear ever to have been thick here, and the outcropping shale did not furnish the waves an abundant supply of material for shore structures. Nearly two miles east of Amherst, at the highway leading directly north, I have mapped two ridges, but I believe that this complexity represents cusp structures rather than distinct beaches. On the hypothesis that the lower Maumee shoreline, in this distance of five miles, did not develop a very sharp beach-ridge, it is possible that weathering has made its detection difficult, and that closer study might give a location to both levels.

Near the boundary between Amherst and Elyria townships the Maumee shoreline turns directly south, and thus continues to

the valley of the West Branch; this section is called "West Ridge." Throughout most of this distance it is a beach, but a cliff, cut in glacial drift, is found not far south of the Lake Shore railway (Southern Division). Just beyond this cliff-phase, a short ridge, on the inland border of the beach, indicates the earliest position of the Maumee level, when the bay extended still farther west. Stream erosion has removed part of the southern end of West Ridge.

Murray Ridge, parallel to this, appears to have originated as an off-shore barrier of the higher Maumee shoreline, which later grew above water and finally became the shoreline proper. It has a strong development, increasing in height and complexity southward. About one mile of the northern part was steepened by wave-work. In texture, the deposits grow finer towards the south. The muck soil between West and Murray ridges indicates a lagoon history; an arm of the lake was shut off completely at the northern end, as shown by the bar joining the ridges; there is evidence that the southern end was once more nearly enclosed than now; some short spits are appended to the inland slope of the beach, one of which may formerly have been connected with the isolated ridge of sand and gravel, outlined by the 750-foot contour, about one mile long, and parallel to West Ridge. Murray Ridge was a shoreline in the closing period of the upper Maumee stage as well as during the lower stage.

Between the east and west branches of the Black river, the upper Maumee level is represented by a well developed shoreline extending southwest from Laporte. This part of the beach consists prevailingly of fine sand. The ridge has a very much sharper front than back slope (fig. 1 A), because of steepening by wave erosion. Between this beach and the southern end of West Ridge, stream work has removed whatever shore development existed in this, the shallowest part of the bay.

East of the river the shoreline is known as "Butternut Ridge," and has a very strong development. For most of this distance the beach is composed of fine gravel and very fine sand; its front slope, as shown by a typical cross-section, is sharp; and there is generally present a lower inner ridge (fig. 1 B). Toward the eastern border of the sheet, the lake side of the ridge is a cliff cut in the drift and shale; a regular beach caps the cliff, showing that the wave-erosion took place just before the close of this Maumee stage.

Lower Maumee stage.—"Chestnut Ridge," which parallels

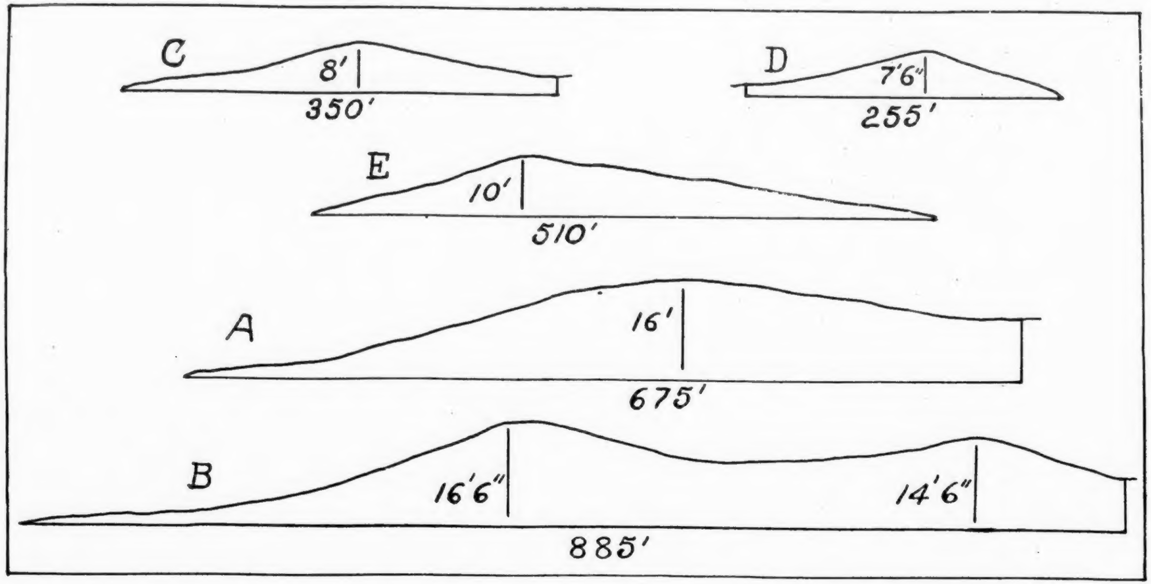


Fig. 1

Cross-sections of the Maumee shoreline, horizontal and vertical measurements as indicated. Consult plate VII for the location of these cross-sections.

Butternut Ridge and is less than half a mile distant, represents the lower Maumee level. It has a slighter development, and consists of finer deposits; eight feet is the usual height (fig. 1 C). Its western end shows successive positions due to the development of spits into the deepening waters of the bay. Many lagoons formerly existed between Butternut and Chestnut Ridges.

Between the two branches of the river I was unable to locate a continuous shoreline of the lower Maumee; it is represented by only one short ridge, consisting mostly of weathered clay, wave-eroded from the subjacent shale, directly south of Elyria.

Sugar Ridge is obviously an off-shore barrier of the lower Maumee stage. It has a symmetrical development (fig. 1 D, E) and, from the numerous bowlders, particularly along its eastern half, I infer that the barrier may have been initiated by an irregular deposit of glacial drift.

Extending northward from a point near the middle of Murray Ridge I have mapped a structure which resembles a barrier through part of its course; elsewhere its strength of development implies a regular shoreline. This inference is based partly on other Maumee deposits directly north, deposits which indicate this level declined gradually, thus converting part of the barrier into a beach.

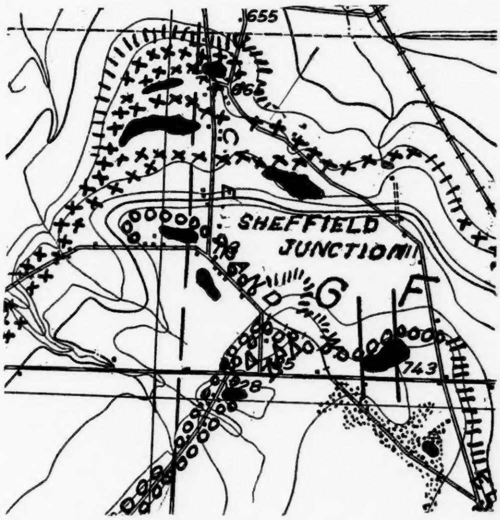


Fig. 2

Cuspate foreland of the Warren stage, south of Lorain. Parts also of the Whittlesey and Maumee shorelines southeast of Sheffield Junction.

Directly north from this locality my map shows scattered Maumee deposits. All of these rest immediately upon the Berea sandstone which in this region has scarcely any covering. The two areas west of the north-south highway consist of quite coarse rubble. The crescent-shaped area east of the highway is made up of slightly finer material; if I had been able to trace beach deposits between this and the arm of sand and gravel extending northward from near the middle of Murray Ridge, I would not hesitate to make it the shoreline of the lower Maumee. The ridge that extends north, crossing the electric line, and bearing thence to the west, parallels a lagoon for seven-tenths of a mile. This ridge increases in strength of development northward; its west or inland slope is short and steep. A recently constructed railroad, about twenty rods south of the electric line, reveals a section; at this point it consists of coarse, well-rounded stones; finer gravel is found as the ridge turns westward. The two short spits are composed of fine sand; one of these so encloses a lagoon (fig. 2) that it is difficult to conceive of its originating in any other way than in very shallow water. It is quite evident that this region of Berea sandstone, north of the Lake Shore railway, formed a shallow place, like a submerged cape, in lake Maumee, and that these scattered areas of beach deposits were constructed during its declining stage.

Islands.—About a mile east of North Amherst, the area marked "Quarry" on the topographic map (fig. 3) formed a small island in the Maumee stage. Its slopes were steepened by wave work; to its eastern end is appended a spit. The part of the island's surface that was above water now bears wind-shifted sands.

THE WHITTLESEY SHORELINE

The Black river depression was occupied by a broad bay during the Whittlesey stage. The outcropping sandstone on the west formed a peninsula, making a break in the regular east-west direction of the shore. The general altitude of Lake Whittlesey is about 730 feet; a beach structure characterizes its shoreline on the Oberlin sheet.

West of Black river.—Near the west margin of the sheet (plate VII) Beaver creek has cut the beach for a short distance. Immediately on either side of this creek the shore ridge consists chiefly of fine sand. To the east, as the shoreline bears northward,

there is evidence of a glacial origin of the beach materials; the large number of scattered bowlders along the shore terrace suggest wave-action on till.

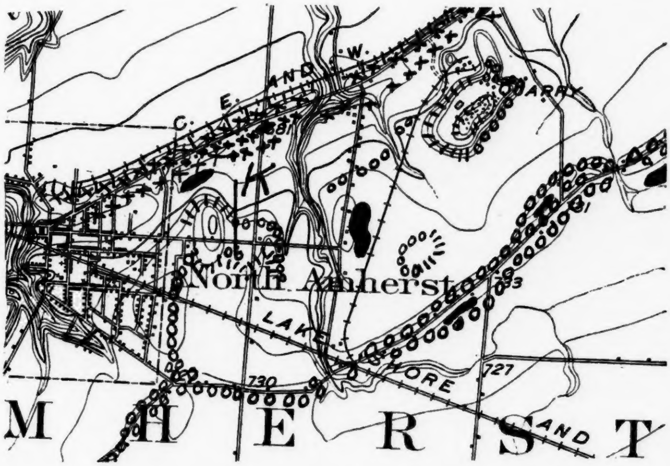


FIG. 3
Shoreline features in vicinity of North Amherst.

The highway trending to the northeast follows the Whittlesey beach ridge. After crossing the Lake Shore railway the ridge is complex, having a lower inland beach. Directly southeast of the "Quarry" a broad cusp was formed (fig. 3). One-half mile southeast of Sheffield Junction the beach contains so much sand that it was drifted by the wind into dunes (fig. 2). Just east of this dune area the shore-ridge has a very sharp development as shown by the profiles (fig. 4 F, G); the original position of the shoreline here was farther inland as suggested by the long lagoon south of the beach. Thence southward for one-half mile the Whittlesey level is marked by a cliff cut in the sandstone; beyond this is a gravel and sand ridge which is followed by the "Lake Road" into Elyria. Near the point where the cliff-phase gives place to structural deposits there are several ridges and intervening lagoons. About one and one-half miles northwest of Elyria, outcropping sandstone again formed a cliff, for about 60 rods, in the Whittlesey shoreline.

The exact course of this beach in the vicinity of Elyria cannot be mapped, chiefly because of stream erosion.

East of Black river.—From the river to the eastern side of the sheet the Whittlesey level is marked by a continuous beach structure, the off-shore slope of which for much of this distance shows steepening by wave-work towards the close of the Whittlesey period.

Throughout most of this distance there is an inner beach ridge of earlier development. About one and one-half miles west of North Ridgeville a third ridge appears. Locally these ridges indicate greater activity of wave and along-shore work, thus piling up heavy beaches and eventually moving the shoreline outward; a cross-section near the east side of the sheet (fig. 4 H) is an example; a similar relationship of the two ridges exists west of North Ridgeville near the second highway leading south. Locally the inner ridge is lower (fig. 4 I); while in places a single beach exists (fig. 4 J).

In the vicinity of Sheffield Junction I have mapped a spit that grew to the northwest from the shoreline proper (fig. 2). This spit, after it crosses the highway leading north to Lorain, has a strong development. Following the decline of the Whittlesey level, a marsh condition existed south of this ridge, as evidenced by the extensive muck areas. The highway from this point to North Amherst formerly followed the ridge, having a more irregular course; later it was changed to its present more direct course across the marsh. From the eastern end of this latter ridge the sandstone forms a low escarpment, swinging southward to the shoreline proper; that this escarpment is the result of wave-work is doubtful.

Islands.—Several outliers of Berea sandstone formed islands in Lake Whittlesey. One such area on the western edge of the sheet eventually became a part of the shoreline itself, through being doubly tied to the shore by bars, a feature that is observed on the next sheet west, the Vermillion. A cliff in the sandstone nearly surrounds the part of this island shown in the Oberlin sheet; a short reach of structural deposits is found on both the north and south sides of the island west of the wave-cut slope.

Just east of North Amherst is another island of this lake stage (fig. 3). The northern side of this is a wave-cut cliff; on the southern side wave-cutting is also recorded, not in rock but in unconsolidated material. A beach is found on the east side, with a spit

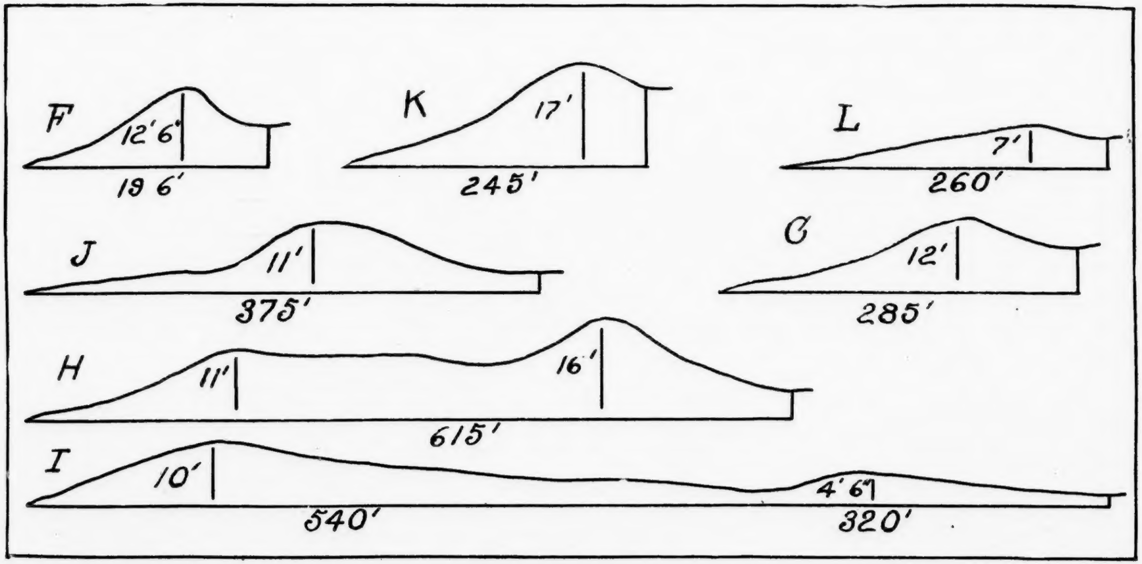


Fig. 4

Cross-sections of the Whittlesey shoreline, horizontal and vertical measurements as indicated. Plate VII gives the location of these cross-sections,

extending eastward for about twenty rods, then turning to the south, its course being deflected by on-shore currents in the deeper water; a profile of the beach west of the north-south highway (fig. 4K) shows wave-erosion. This island was tied to the shore by a spit which grew landward from its southwestern side; the texture of this bar is coarser near its island end; at the southern end it consists of fine sand and gravel, forming a cusp-like union with the beach.

About one-half mile east of this island, I have indicated on the map another small area which was above water during the latter part of the Whittlesey stage. On the eastern side of this there is evidence of some wave-work on the sandstone; elsewhere its shore is marked by beach material. In origin this island appears to represent a local arching of the sandstone. The whole surface is strewn with slightly worn blocks of the thin layers found in the upper part of the Berea formation.

The only island on the sheet belonging to the Maumee level, as already noted, is one-half mile farther northeast; during the Whittlesey stage its area was about four times as great. Its western half has a wave-cut cliff; elsewhere its shore is marked by structural deposits. Short spits extended from the northeastern quarter, one growing almost directly north and the other bearing to the east. Wind-deposited sands are noted also in connection with the Whittlesey beaches, about this island.

The road extending southward from Avon (plate VII) leads across a long ridge due to an arching of the Berea sandstone; the attitude of the beds is revealed in a railway cut made directly across the ridge. This arching caused a shallow place in Lake Whittlesey, and led to the construction of a barrier. Apparently the Whittlesey level fell slightly and a spit was developed to the southwest; this spit consists of very coarse material, the product of wave-work on the thin beds of the Berea; the part of its course that parallels a north-south highway is a strong ridge; north of this point its cross-section (fig. 4 L) shows that the lake-level fell enough to subject the tied end of the spit to wave-attack. Opposite the northern end of "Rocky Ridge" is a shorter ridge of gravel and sand which originated as an off-shore barrier. Paralleling the southern part of Rocky Ridge, and east of it, is another off-shore barrier.

Between the Wheeling Railroad, and the Lorain and Elyria

Electric line, about one-half mile south of the northern boundary of Elyria township, I have mapped two areas of Whittlesey gravels. The eastern one lies between the 690 and 700-foot contours, according to the map. It is quite certain that the sketching on the topographic map is in error at this point. The Whittlesey structures here shown are spits of rather coarse materials, built from an island outlier of Berea sandstone the shape of which is roughly shown by the 700-foot contour. This outlier has a long east-west axis. According to the hand level its top is approximately on a level with the "Lake" road, one-half mile southwest—i. e., the altitude of the outlier is about 730 feet. From its southwestern corner another spit of coarse gravel material was developed; these gravels terminate near the Wheeling track. Apparently a wave-cut cliff once showed entirely across the north side of the island, where a quarry is now located.

THE WARREN SHORELINE

The altitude usually given the Warren stage is 660 to 670 feet. According to the contours, some of the ridges which I have mapped under the Warren stage rise a few feet above the 670-foot contour.

The Black river depression did not make much of a bay in Lake Warren. The irregularity of its shoreline is due to the irregular outline of the Berea outcrops. At two points this sandstone had a cusp-like extension into the lake: at Avon Center and at Sheffield Junction. West of the latter place the escarpment is cut up into outliers. Between these two capes the sandstone has been removed for some distance southward, a fact that accounts for the course taken by the drainage.

On this sheet Lake Warren had no islands. Only shale outcrops beneath the Berea, the Bedford here not having the "Bluestone" phase which it contains farther east. Weathering proceeds so easily and so regularly in mud rocks that the surface keeps uniform, except during the early part of an erosion cycle.

West of Black river.—West of Beaver creek the Warren level appears first in an inner, lower ridge. A short distance north of this is a strongly developed beach steepened by wave erosion; an outlier of sandstone nearby on the Vermillion sheet furnished an abundant supply of beach-making materials.

From North Amherst to the neighborhood of Sheffield Junction, the Warren beach consists of two and sometimes of three

ridges. The outer shows the effects of wave-work; for three miles the base of the cliff is cut into drift. The numerous glacial bowlders attest the removal of drift by currents and waves.

Directly south of Lorain the northward extension of the Berea formation led to a variety of off-shore structures which gave the shoreline a cusp-like protrusion farther into the lake (fig. 2). This area is a typical example of the cuspate foreland; its growth represents the progressive enclosing of lagoons. After a static profile had been reached, wave-work made the cliff which now borders the foreland. The initial position of the Warren beach here is easily traced by a ridge that continues east-west south of the foreland.

Proceeding eastward the Warren shoreline bears to the south; for a short distance, just west of the Wheeling railway, it has a cliff-phase. This railroad crosses three beach ridges and intervening lagoons. It is evident that in the early part of the Warren level the shoreline had temporary positions farther south in the Black river Bay. Several sand and gravel ridges trend southward; some of these terminate at the edge of the river cliff; others have been eroded by its tributary streams, or by earlier positions of the river itself. The multiplicity of ridges on either side of the river show that this shoreline was gradually given a straighter course by the development of spits into bars which, during post-glacial times, have been dissected by the Black river. The irregular course of the Black river in crossing the Warren shoreline reflects the influence of these beaches.

East of Black river.—From the river to the vicinity of Avon many distinct ridges have been mapped. Part of these had a spit origin; others were off-shore barriers first and beaches later. I have indicated some of the numerous lagoons that existed between the ridges. These ridges increase in degree of development towards the north; the one farthest south is short and low; the next one north is broken, and has a sharp bend due to a slight irregularity in the land surface. I made careful search west of the river to find correlating ridges; the map shows all that exist now.

In the vicinity of Avon Center is another cuspate foreland (fig. 5). This, however, differs from the one south of Lorain in that its northern extension includes an outcrop of Berea sandstone which early in the Warren stage was probably an island, and was

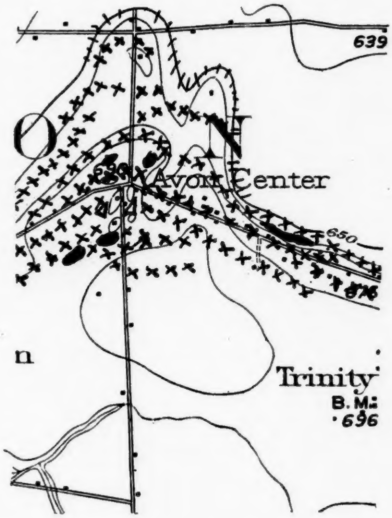


FIG. 5
Cuspate foreland of the Warren stage

eventually tied to the shore. The ridges, south as well as north of Avon Center, are of the cuspate type, showing how this foreland was progressively extended by the deposition-work of interfering currents. The shoreline between the foreland and the eastern margin of the sheet consists continuously of two distinct ridges, and for part of the distance of three ridges.

Before the close of the Warren stage, as shown by nearly the entire reach of the shoreline, the waves and along-shore currents had accomplished their maximum of structural work; then cliff-cutting prevailed. Even where the beaches are best developed the off-shore slope is much steepened. For several miles east of the river a strip of muck or lagoon soil borders the beach cliff; north of the muck is sandy clay, both apparently at the same level. Initially the clay was a low barrier, but high enough to make a marsh. Accordingly it appears that Lake Warren had an intermediate slight

fall in level before the great drop which converted its marginal parts into a lake plain.

DRAINAGE CYCLES

The Oberlin quadrangle shows concisely the relationship that arises from succeeding base-levels each of which interrupted a normal development of drainage lines; it also shows the influence that formations of simple structure and varying hardness have on the growth of valleys, a factor that may be more effective relatively than time in producing the several stages in the cycle of erosion. The erosion cycles here are not as simple as they would be if each had commenced on a normal consequent surface. Preglacially the region had been subject long to weathering; its rock structure is such that the area has preserved this older erosion pattern; to a slight extent only did the distribution of glacial drift change this former topography.

The Maumee base-level.—The definite level of the upper Maumee in this region must have been preceded by a minor body of water occupying the depression indicated now by the branches of the Black river. This condition, however, did not endure long, as no shorelines marking the lake have been found.

The Maumee shoreline has an altitude of about 770 feet. South of this the surface configuration is influenced by the Berea sandstone, over which is a covering of shale so thin that a slight amount of channeling places the streams on the more resistant rock. The Berea here is heavy and has a mild dip to the south. The northward slope of the preglacial surface was gentle.

The amount of slope for several miles south of lake Maumee was so slight that the drainage pattern formed was but little more developed than a true consequent surface would give. The fall of these streams was so gentle that the beach diverted them towards particular points, at which they cut the ridge when the Maumee level declined. At Laporte the streams from east and west converge and cross the beach ridge. This branch of the Black river has not made much of a channel in the Berea sandstone; north of its intersection with the Lorain and Wheeling railway, glacial drift forms its banks; south of this point, it has cut slightly into the Berea.

The West Branch apparently is following an earlier valley

which was partly filled with drift. Its irregular course still preserves the meanderings of the consequent stream which flowed into lake Maumee. Its tributaries are quite numerous relative to the small areas which each controls; and the width of its valley corresponds to the long period of erosion.

The Whittlesey base-level.—Lake Maumee was lowered about 40 feet in establishing this level; the drop was not accomplished at once, as is evidenced by the lower Maumee beach. Furthermore, the multiplicity of barrier beaches, belonging to the Maumee level, indicates a halt in the change.

The two branches of the Black river converge more when brought under the control of the Whittlesey base-level, a fact due to the shape of the preglacial basin which occasioned the local bay in Lake Maumee. The 40 feet of fall added to the stream slope did not have much effect on their erosive powers in the Maumee part of their courses. This 40 feet is in the Berea sandstone, which is quite resistant, and in all post-glacial times has not been cut down so as to materially increase the gradient upstream.

Laterally from the depression in which Elyria lies the streams connected with the Whittlesey base-level were few and of slight development. Beaver creek, on the west side of the sheet, has made more of a valley than either branch of Black river; this is due to a steeper initial slope, and to the shorter distance through which it had to channel the Berea sandstone.

The Warren base-level.—The difference in altitude between this and the Whittlesey level is about 60 feet; the drop appears to have been accomplished quickly. The accession of drainage territory was not great because west of Black river the Whittlesey and Warren shorelines are close together.

In this change of level, Black river was lengthened by about four miles; the slope of this added length originally could not have been over 60 feet. The stream therefore took a somewhat irregular course, which it still preserves. Its channel lay across a slight depth of glacial drift beneath which the rock is an easily eroded shale; consequently this four-mile section was not long in reaching the new base level. During the existence of Lake Warren, the stream appears to have added about a mile to its length lakeward, gaining through the off-shore development of barriers which eventually became the shoreline proper; the river deposits account for this prograding shoreline. These earlier formed ridges exercised an

influence on the direction of the river, as the development of the highest Warren beach here was sufficient to turn the course of the stream to the west about one-half mile.

It is evident that Black river had a falls over the Berea sandstone a short distance north of the point where the two branches now meet. Since that time the falls have moved up-stream not much over a mile. North of the outcropping Berea the river has had easy work in the shale; it has developed many small tributaries considering the small area drained.

In the region south of Avon Center only one stream, the headwater part of French creek, appeared after the Whittlesey decline; this flowed into the lake near Avon. The drainage from the area north of Butternut Ridge escaped across the Whittlesey beach, thence to the Black river. Different segments of this stream show the directive influence of beach ridges.

West of the Black river the two beaches are so close together that few streams developed save continuations of those that were already tributary to Lake Whittlesey; these were lengthened usually by one mile, the average distance between the two beaches. Beaver creek, however, responded most successfully to the added 60 feet in gradient; south of North Amherst it has made much progress in valley development, considering the resistant rock in which it is working.

Lake Erie base-level.—Lake Warren dropped about 95 feet in establishing this new base-level. The added drainage territory is entirely in shale, with a very slight veneer of glacial drift. This easily eroded rock has given the streams which cross it an appearance of greater age than these same streams show in the much older parts of their course. Both Black river and Beaver creek have developed relatively wide valleys, which they are still broadening by lateral erosion. These two streams control so completely the drainage territory south that the shore of Lake Erie is creased by only a couple of other creeks that have as yet accomplished much erosion. Two slight streams near Beach Park have cut the shales back, developing youthful valleys. West of Black river, Martin run has made a longer and slightly wider valley.

Summary.—In the northern fourteen miles of its course, Black river has been subject to four base-levels. We have no data for satisfactorily measuring their relative time periods. The Berea

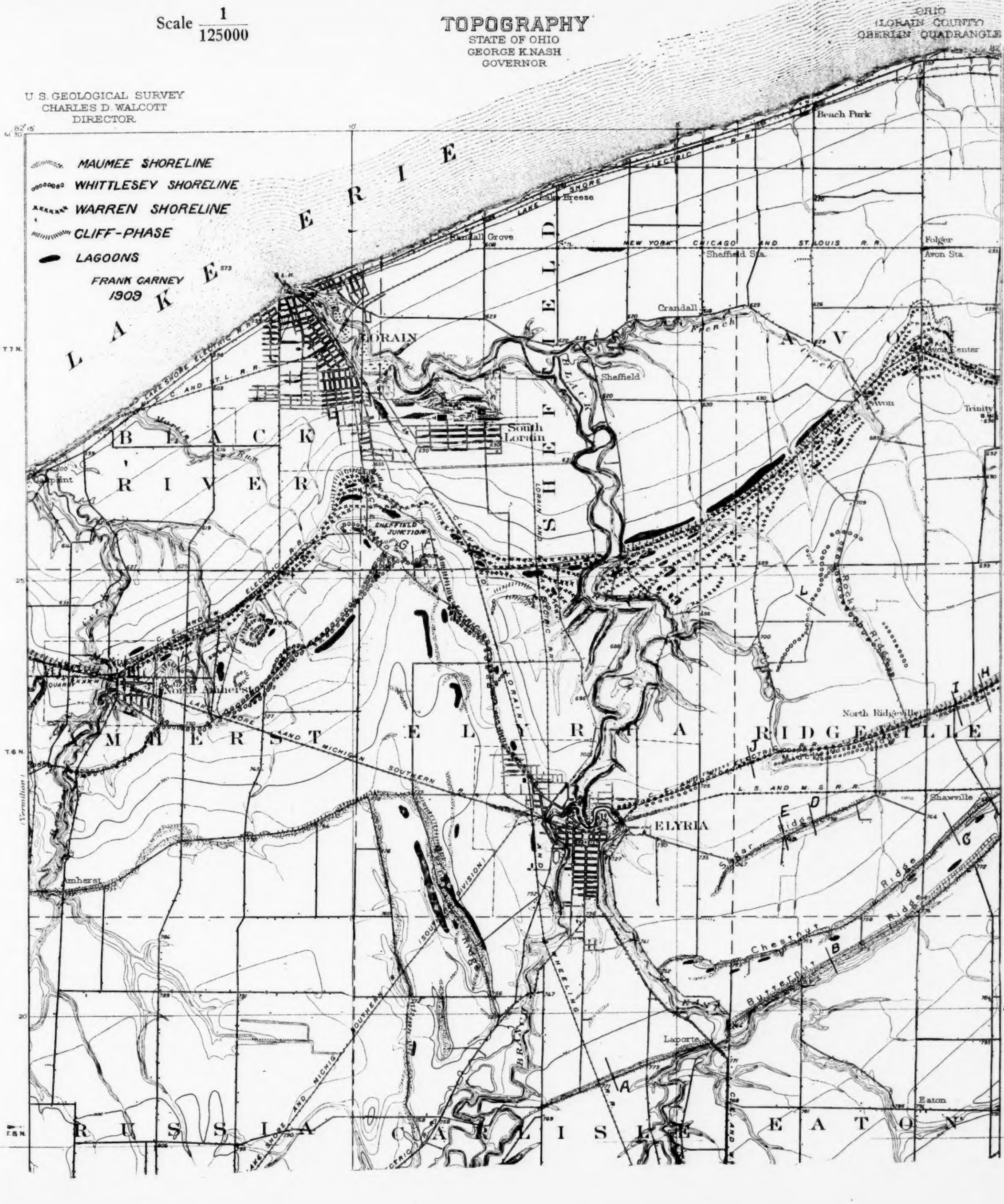
sandstone, which it crosses at Elyria, forms a local base-level for the river south of this place.

In the last six and one-half miles of its valley, the fall of the river is about seven feet, approximately a foot per mile. North of the Warren shoreline, it discontinued down-cutting long ago; its further work, in reference to the present base-level, will be entirely lateral plantation, the process which has already widened the valley in some places nearly a half mile. When the Lake Erie level was inaugurated, this portion of Black river had a descent of 95 feet.

In the interval of approximately five miles between the Warren and Whittlesey shorelines the initial slope was about 60 feet; the fall of the stream is now about 70 feet; the gain in gradient is a response to the Erie base-level. Much more erosion has been accomplished than would appear to be the case from these figures, as part of the 80 feet of channel-cutting involves the resistant Berea sandstone. The width of the main valley, its numerous tributaries, and their maturing cross-section, show that the Whittlesey part is much older than the Warren part of the river.

In the Maumee section we would expect even greater evidence of age. But here the time factor is offset by the hard rock the river has had to work on; its valley is shallow, and there are few tributaries. South of this highest shoreline, the surface is more creased by stream courses with somewhat wide valleys.

Plate VII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